# The Mechelecit

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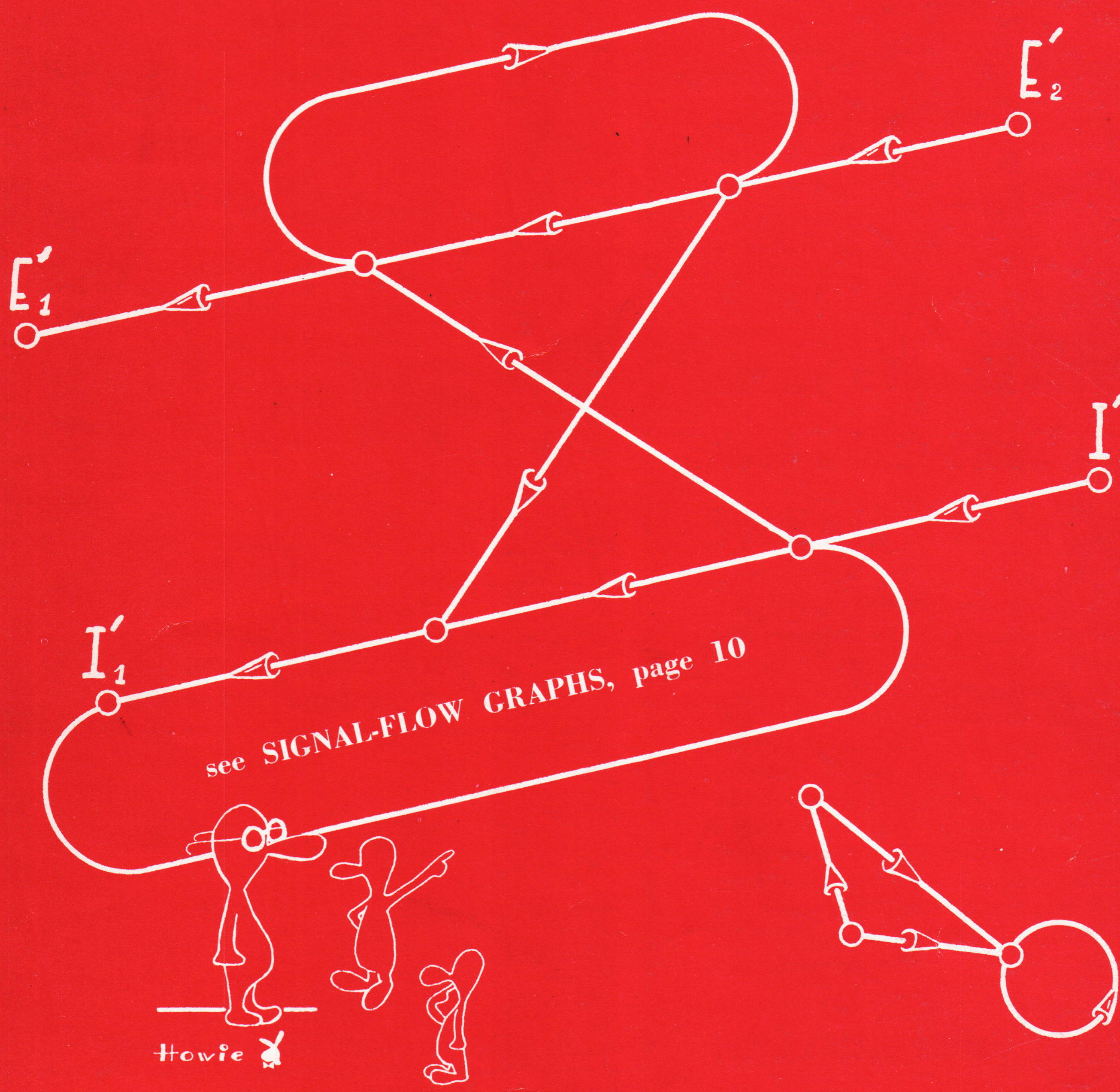
THE GEORGE WASHINGTON UNIVERSITY ~ SCHOOL OF ENGINEERING ~




## THE GEORGE WASHINGTON UNIVERSITY

MAY 1960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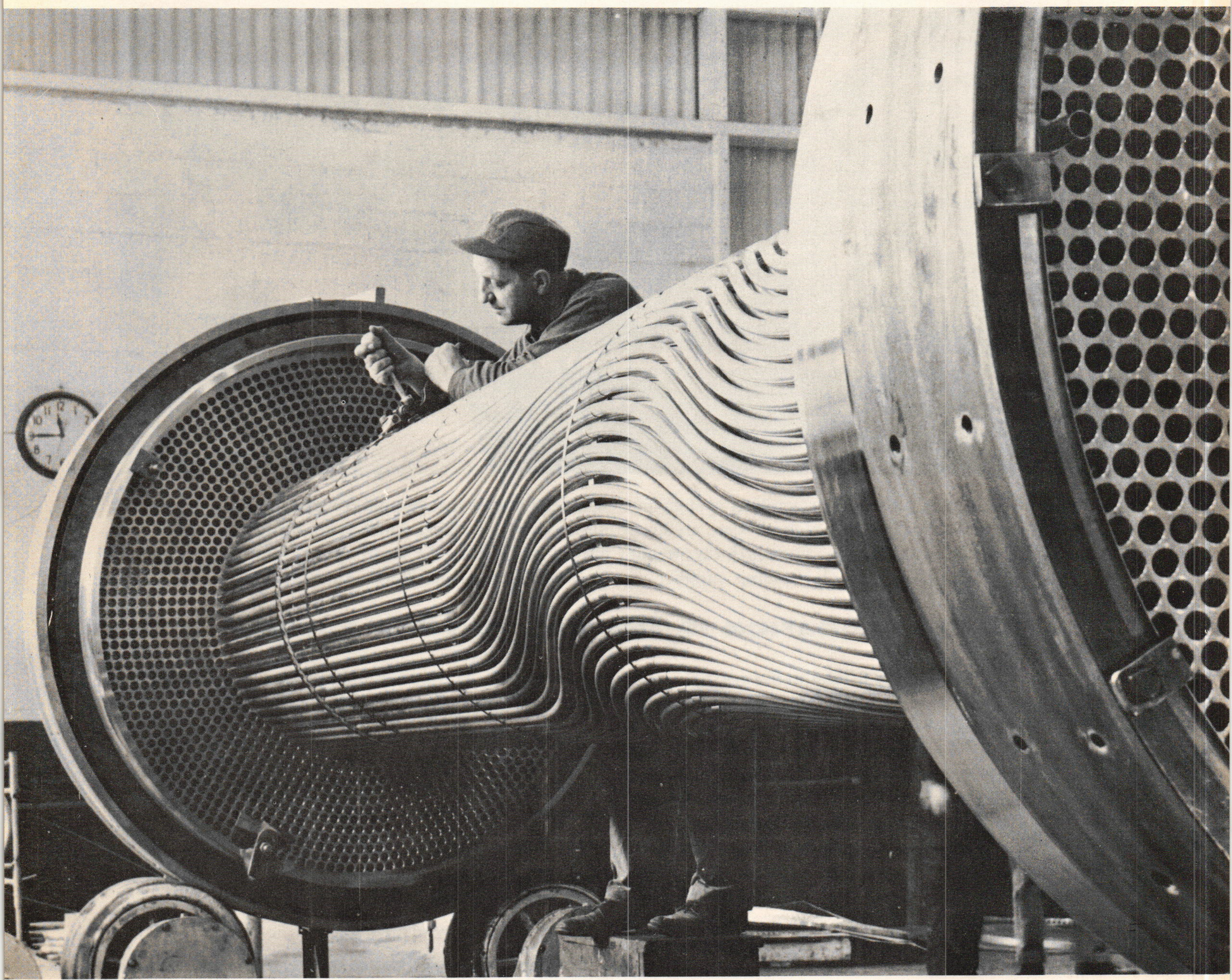

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## ARTICLES



## DEPARTMENTS



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# Editorial Page

## "ACADEMIC FREEDOM"?

A constant complaint of a small group of students active in school events is the so-called apathy of the majority of the student body. This apathy extends from non-participation in activities to not voting in the elections.

These individuals feel that since a person is in college it is his duty to participate in school activities and to have "school spirit." The slogans used in the campaign to sell "school spirit" to the masses of uninterested students too often imply that those students are guilty of neglecting their school duties.

It is our impression, however, that the majority of college students are here to get a degree, or, to put it better, to get educated.

Despite a detailed search of all the university bulletins no regulation was found saying that a cheerleader's job or the chairmanship of some event are prerequisite to graduation. We are not looking down on these energetic individuals who, through widely diversified motives—from desire for recognition to genuine civic interest—, are expending considerable time and effort to brighten the dull academic life. They are doing a good job although they don't have to do it. The point where they fall down on their job is where they accuse the other students of apathy. Somebody is to be accused of apathy if he is neglecting his duties; and in this school all the students except the ones that get F's are fulfilling their obligations to various degrees.

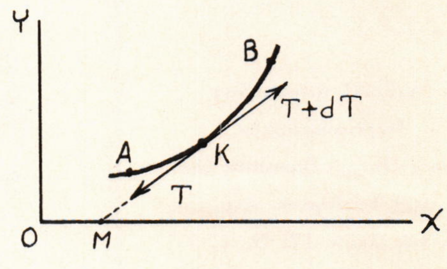
The non-academic activities can be pointed out, and the interested persons should participate. The others should be left alone to pursue their objectives in the way they best see fit. The adjective, apathetic, should not be applied where it does not belong. The freedom of the student *not* to do something is also part of the academic freedom.

## MONTHLY QUIZ

### A PROBLEM IN DYNAMICS

*by James Clerk Maxwell*

An inextensible heavy chain
Lies on a smooth horizontal plane,
An impulsive force is applied at A,
Required: the initial motion of K.




***Answer on page 38***

# THE THIRD REVOLUTION IN COMMERCIAL AVIATION

**by THOMAS E. MILLER, C.E. '60**

The age we are living in today will be recorded in tomorrow's history books as the dawn of the jet era in commercial aviation. In a little over two years the whole aviation industry has undergone a complete revolution. Today it is possible to fly from coast to coast in 4½ hours and from North America to Europe in 6½ hours, whereas in 1958 it took from two to three times that long. The cause of this revolution is the emergence upon the scene of economical commercial jet aircraft. These aircraft offer to the flying public a whole new concept in travel, just as the automobile did following the horse and buggy era.

For all practical purposes the race to fill the needs of the world's airlines for jet aircraft is a race between the four major countries of the world; Great Britain, France, The United States and The Union of Soviet Socialist Republics. Each country's aircraft are designed for specific purposes, with the U. S. and the U.S.S.R. having the widest variety of types. Great Britain held the lead in 1953 and 1954 with their Comet I. The lead next went to the U.S.S.R. with their Tu-104. At the present it now rests in the U.S. How long it will stay here or where it will go next depends upon who can produce a better aircraft next.

Jet aircraft fall into two categories, the turbojet or pure jet, and the turboprop or propjet. The U.S.S.R. is basing its hopes for world recognition on turboprop aircraft such as the mammouth Tu-114 and the intermediate Il-18; while the U.S., taking just the opposite view, on turbojet such as the Boeing 707 series, the Douglas DC-8 and the Convair 880 and 600.

United States built aircraft have been purchased and placed in service by airlines in all parts of the world, except the Soviet bloc. The Soviet planes have been put into service by the Soviet state-run airline Aeroflot, which is the largest commercial airline in the world.

## FIRST SUCCESSFUL TURBOJET

In the spring of 1956 the Soviet run airline Aeroflot surprised the world by introducing the Tu-104 on its air routes. The Tu-104 which was designed by Anatoli Tupolev, could carry only 50 passengers in its original model and its interior was reminiscent of the railroad furnishings at the end of the nineteenth century. By expanding its original length of 121′ the latest version, the Tu-104B, will carry up to 100 passengers in a five abreast seating arrangement. The two Mikulin turbojets have been raised from their original 14,800 lb. thrust to 15,000 lb. thrust and on flights from 500 to 1500 miles, the Tu-104B, unlike its predecessor, is now an economical airliner. The Tu-104's biggest problem is in landing. Because of the lack of thrust reversers on the two Mikulin engines heavy braking is required and many planes have had their brakes burnt out or have had blown tires. For this reason Aeroflot has requested that water hoses be available at foreign airports to douse the Tu-104's smoking brakes. The Tu-104, like most Soviet airliners, is equipped with extremely small doors which require stooping upon entering.

The engines on the Tu-104 are an integral part of the wing and are located very close to the fuselage of the aircraft. Of interesting note is the fact that the Soviets have been unable to sell any of their Tu-104's except to Czechoslovakia, although it is the mainstay of their airline. In fact they haven't even been able to give them away.

## BRITISH ENTRY

The entry in the jet race from Great Britain is the de Havilland Comet 4, which is being produced at both Hatfield and Chester.

The Comet 4 is an outgrowth of the ill-fated Comet 1's which cracked up in 1954 because of failure due to fuselage cabin fatigue. The Comet 4 resembles the Comet 1 in many details but is completely redesigned internally, making it a safe sleek-looking aircraft. The first of this series flew on April 27, 1958. Basically the Comet is a medium range aircraft but BOAC, the British national airline, put the Comet 4 into service on the North Atlantic run from London to New York.

De Havilland offers the $3 million plus aircraft in three forms to cover different operational roles. The Comet 4, which is intended for the world's trunk routes, carries from 60 to 81 passengers on routes up to 3,225 miles at cruising speeds of 500 miles per hour. The Comet 4B, intended for inter-city networks, is designed to carry up to 102 passengers on routes of 400 to 2,500 miles at speeds of 530 miles per hour. The Comet 4C will fly up to 2,820 with a passenger load of from 72-102 at speeds of 500 miles per hour. The intermediate 4C offers the larger capacity of the 4B while having a range of some 250 miles greater. All three aircraft are powered by 4 Rolls Royce Avon fully anti-iced Ra 29 Mark 524 engines of 10,500 lb. takeoff thrust each. Like the Tu-104 the Comets' engines are an integral part of the wing nestled close in to the fuselage. Each of the engines is fitted with Rolls Royce

corrugated nozzle noise suppressors which give a reduction in noise level of 3 to 5 db.

At the present, de Havilland has firm orders for 33 Comets and figures its break-even point is between 60 and 70 aircraft.

## UNITED STATES AIRCRAFT

In 1954 at a cost of $16,000,000 of its own money the Boeing Aircraft Company produced the United States' first commercial jet aircraft. Out of this prototype have come the five members of the Boeing family of jets, the 707-120, 707-220, 707-320, 707-420 and the 720.

The 707-120 was put into intercontinental service by Pan American World Airways in October of 1958 and in transcontinental service by American Airlines also in October of 1958. The 707-120 is 144′ 6″ long, 38′ 8″ high and has a wing span of 130′ 10″. It is powered by four Pratt and Whitney JT3 turbojet engines of 10,000 plus lb. thrust. The 120, intended primarily for continental use, can carry from 100 to 179 passengers at a cruising speed of 589 miles per hour on routes up to 4,000 miles in length. The 707-220 is the same size as the 120 but is powered by more powerful Pratt and Whitney JT4 engines. The intercontinental versions of the 707 are the 320 and the 420 which are exactly alike except for power plants. The 320 is powered by Pratt and Whitney JT4A-11 engines and the 420 is powered by British built Rolls-Royce Conway engines. Most European countries and countries in the British Commonwealth have picked the Conway engines because of the greater ease of maintenance. The 707 Intercontinental is 8′ 5″ longer and the wing span is 11′ 7″ more than the 120, the height remaining the same. The cruising speed of the Intercontinental is over 600 miles per hour.

The Boeing 720 is designed for the medium range field and will carry up to 149 passengers in a tourist configuration. The 720 has a cruising speed of 614 miles per hour and will fly a full pay load range of 3,300 miles. The first of these planes will be delivered to United Airlines in April of 1960. Later models will be powered by the JT3D turbofan engine. The 720 is 8′ 4″ shorter than the 120 and is 45,000 lbs. lighter.

## COMING THIS YEAR

Still to enter commercial service is the Convair 880. This plane first flew in January of 1959 and the first aircraft will enter commercial service with Trans World Airlines in the Spring of 1960.

This aircraft was designed to utilize existing airport facilities and to bring commercial jet travel to short and intermediate range flights. It is capable of using 150 present day medium length airports in the United States.

The 880 is 129′ 4″ long with a wing span of 120′ and a maximum height of 36′. It is capable of speeds in excess of 615 miles per hour.

Power is supplied by four General Electric CJ 805-3 turbojet engines equipped with sound suppressors and thrust reversers. The engines, like the engines on the Boeing jets, are installed in pods attached to pylons suspended from the wings.

The domestic Convair 880 is designed to operate on flights from 300 miles up to transcontinental flights. In a first class four abreast seating arrangment 88 passengers can be accommodated on flights up to 3450 miles. In a five abreast arrangement it will hold up to 110 passengers. The intercontinental version of the 880 will fly up to 4210 miles.

## FASTEST

The Convair 600 will be the first transcontinental airlinei designed for operation at near sonic speeds. With a cruising speed of 635 miles per hour it will be the fastest airliner in the world. This aircraft is a medium range jet with long range capabilities. With full fuel load it is capable of flights up to 4400 miles.

The 600 will be powered by four General Electric CJ 805-21 aft-fan engines. The CJ 805-21 provides greater thrust and lower cost of operation through utilization of the bypass-air and fan principle.

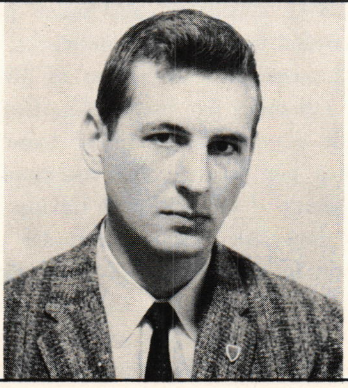
Like the 880 the 600 has been specifically designed for operation from airports presently designed for propeller-driven aircraft.

The maximum dimensions of the 600 are the same as the 880 except it is 11′ 3″ longer. In full tourist configuration it will seat 121 passengers.

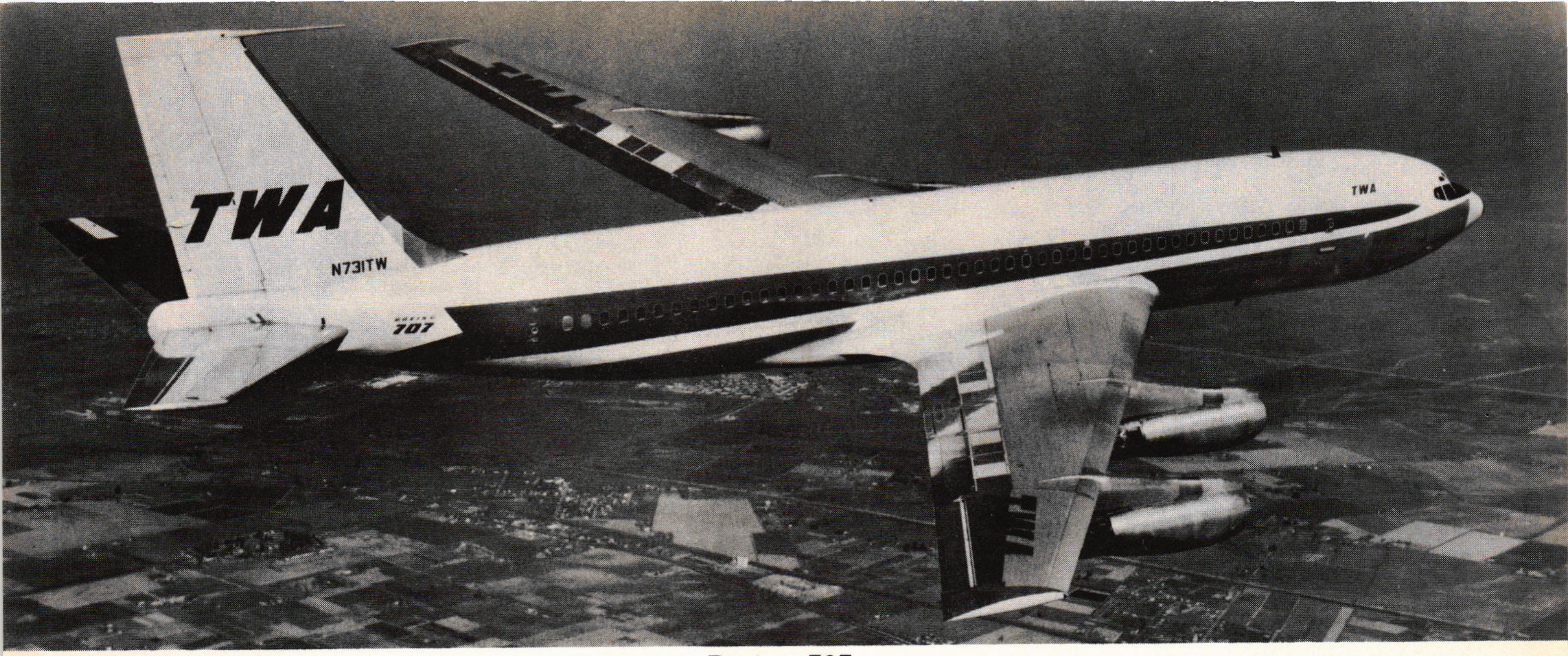
The striking outward features of the 600 are the Aerodynamic Anti-Shock bodies located on the trailing edge of the wings. They dissipate shock wave buildup on the wing during operation in the higher mach ranges. Extra fuel capacity for long-range operation is also provided in the Anti-Shock bodies.

## FROM DC-3 TO DC-8

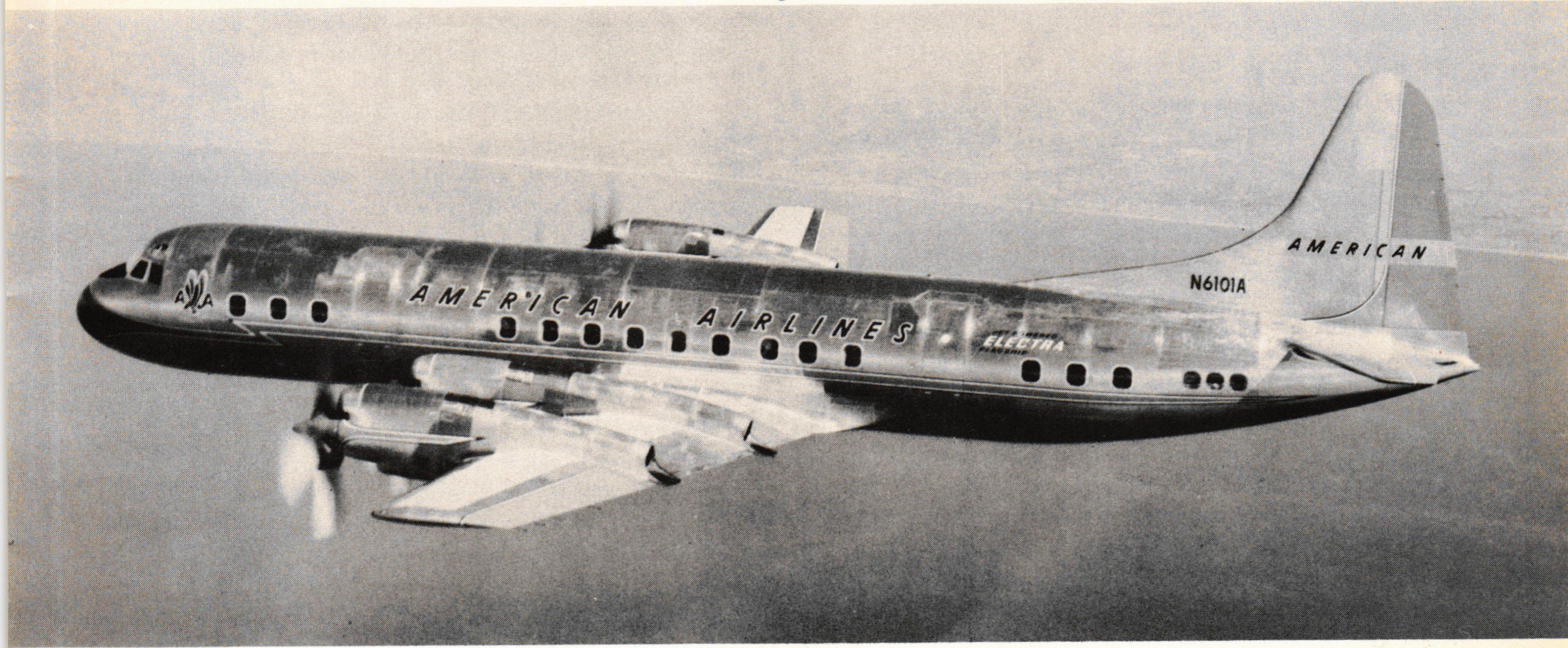
The latest in the DC (Douglas Commercial) family of planes to emerge from the Douglas Aircraft Co. plant at Long Beach, California is the DC-8. The DC-8 first flew for a commercial airline on September 18, 1959 when



**Tom Miller, a senior in Civil Engineering, was born in Bellingham, Washington in 1935. He attended high school in his home town and came to George Washington in Sept. of 1955 by way of the University of Washington. Tom is married and has a brand new baby boy. He works part time in the U. S. Senate and part time as a student assistant in the dept. of Civil Engineering, and is a member of ASCE and a member of the board of editors of MECHELECIV.**




*Boeing 707*




*Lockheed Electra*


*Convair 880*

United Airlines and Delta Airlines placed it in service simultaneously.

The DC-8 comes in five models all having identical outside dimensions differing only in weight due to added fuel capacity and structural accommodations on intercontinental models. The four engines come in three models, the Pratt and Whitney JT3 and JT4 and the Rolls Royce Conway. Each engine is equipped with a thrust reversing mechanism. With this feature landing distances are shorter, brake maintenance is reduced and wet and icy runway operation is improved.

The DC-8 will carry from 116 to 176 passengers at a maximum cruising speed of 593 miles per hour. Maximum stage length of the intercontinental model is 5930 miles.

To a casual observer not familiar with today's aircraft it would be hard to distinguish one American-built jet from another. All three of them have the same general outward appearance as the accompanying photographs show.

**PRIDE OF THE FRENCH**

The Caravelle is a twin-jet short-to-medium range airliner powered by two Rolls Royce Avon MK 527 turbojet engines rated at 10,700 lb. thrust each. The engines are located in pods attached to the tail section of the airframe. Mounting of the engines on the tail cuts cabin noise and reduces the dangers of jet blast damage. This ingenious way of attaching the engines is a complete departure from previous engine attachments. The airplane was designed by Sud-Est and was ordered in prototype form by the Secretariat d'Etat a l'Air in January of 1953. The first of two prototypes flew on May 27, 1955, and the second on May 6, 1956. The Caravelle is now flying for Air France, SAS, and REAL Airlines of Brazil. In this country United Airlines is seriously considering the Caravelle for its short hauls below the Boeing 720's economical range.

REAL is using the plane for its flights from Brazil to New York, while SAS is using it on its European runs and Air France on its Paris-Moscow flight.

The Caravelle is capable of carrying up to 80 passengers and of flying at speeds of 510 miles per hour.

The Caravelle production is being undertaken by a large number of French factories with the final assembly being done at the Sud-Aviation plant at Toulouse.

**SOVIET GIANT**

In the turboprop field the giant is the Soviet built Tu-114. This airplane was designed for long haul international routes such as Moscow-New York, a distance of 5,092 miles, which it can fly non-stop with a load of 120 passengers. The Tu-114 is powered by 4 NI-12 12,000 esph turboprops, each mounting 18.3′ diameter counter-rotating propellers. The Tu-114 is the largest commercial airliner flying in the world. For short haul routes this aircraft can carry up to 220 passengers. Its top speed is 540 miles per hour and its cruising speed is 450 miles per hour. It can lift a pay load of 370,000 lbs.

Because the aircraft sits so far off the ground a special unloading ramp had to be constructed at Andrews Air Field for the arrival of Nikita Khruschev, all of our conventional ramps being too small.

The Soviets claim this airplane is cheaper to operate than either a Bristol Britannia or a Lockheed Super Constellation.

The aircraft has an overall length of 177′ and wing span of 180.5′ and a gross weight of 240,000 lbs.

For medium range domestic and international routes the Soviets have their much publicized Ilyushin Il-18. This aircraft is powered by four Ivchenko Ai-20 4,000 esph turboprop engines. This aircraft was designed for service on route segments beyond the range of the Tu-104 of 1,500 to 2,700 miles, where paved runways are available.


*Comet 4*

*Tu-114*

The Soviets also have another four engine turboprop, the An-10. This is a high-winged aircraft which is designed specifically for operation off of grass runways. With this aircraft they hope to offer modern jet service to all parts of the Soviet Union.

Over here the main turboprop is the Lockheed Aircraft Corp. built Electra. The Electra first flew in 1957 and was put into service by Eastern Airlines early in 1959.

The Electra is designed primarily for heavily traveled short to medium range routes, although the craft is capable of transcontinental nonstop flights. However, it specializes in economical operation on shorter routes.

The airplane is 99′ long, 104′ 6″ wide and 33′ high. Power is supplied by four Allison 501 propjet engines developing 3750 horsepower each and Aeroproducts 606, or Hamilton Standard four-blade propellers.

The Electra can carry from 66 to 98 passengers depending upon the length of flight. Maximum range is 3,400 miles.

## REPLACEMENT FOR THE DC-3

Intended specifically for the short feeder airlines the Dutch designed American built Fairchild F-27 turboprop offers jet plane service to the most neglected part of the airline industry (Equipment wise). West Coast Airlines put the F-27 into service on September 28, 1958. The F-27 offers seating arrangements for up to 44 passengers in pressurized air-conditioned comfort. The aircraft has a range of 1700 miles at a cruising speed of 280 miles per hour. It is powered by two Rolls Royce RDa 6/Mark 511 turboprop engines. The F-27 is a high winged aircraft which makes for perfect visibility for all passengers.

## MOST EXTENSIVELY USED

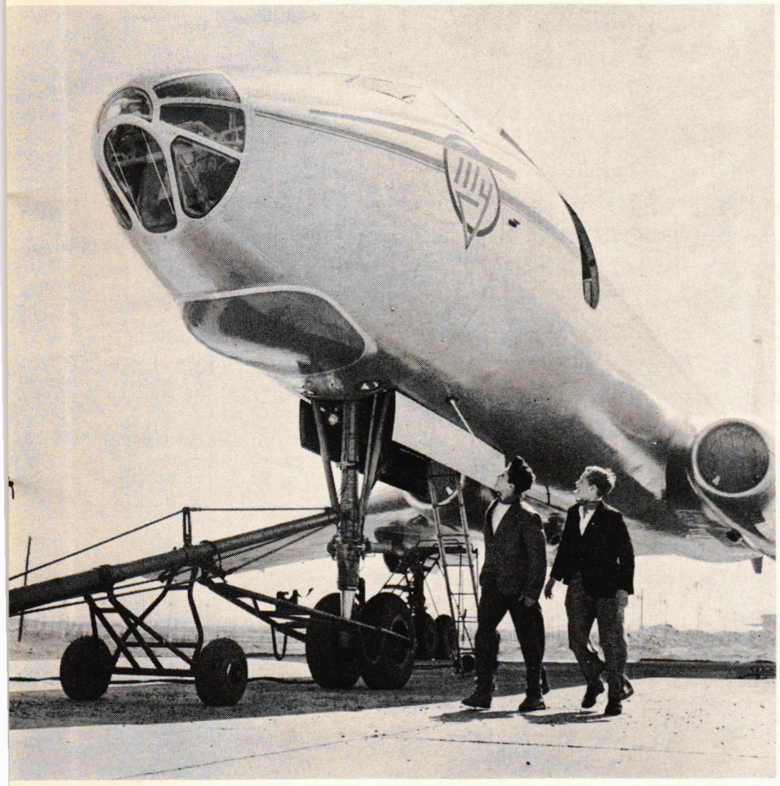
The world's most extensively used turboprop is the British built Vickers Viscount. One of these aircraft may be seen by going out to National Airport almost anytime of the day or night. It is a low wing four engine aircraft, powered in its latest model by Rolls Royce Mk. 525 engines of 1990 tehp. It will carry from 52 to 73 passengers at speeds up to 370 miles per hour.

A striking feature is how a country's commercial aircraft are so similar to their military aircraft. Compare the U.S. aircraft to the B-52 and B-47, then compare the Comet to the British V-Bombers, again compare the Tu-104 and the Tu-114 to the Soviet built Bear and Bison bombers. In the case of the Soviet built planes one might think they have just taken out the bomb bays and inserted passenger seats.

## CONCLUSION

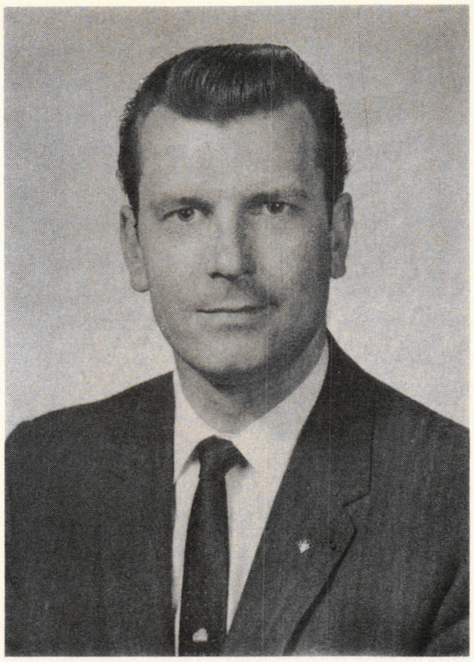
The aircraft equipment just mentioned represents a multi-billion dollar investment to the world's airlines. Now that these aircraft are available there are several grave questions staring the industry square in the face; where will the money come from to buy these multi-million dollar craft, where will the passengers come from to fill them and probably the most serious problem of all, what is to be done with the piston aircraft the jets will replace. These are real problems, but they will be solved because they must be solved.

What is coming tomorrow? Well that is a highly debatable question. Tomorrow will probably bring with it the Mach II or Mach III aircraft. When will tomorrow be? — who knows? But something that is known is that when tomorrow arrives it will bring with it another revolution in the airlines industry just as the DC-3 did in the 30's, the four engined piston aircraft did in the 40's and 50's and the jets are doing today.



*TU-104*


*Douglas DC-8*



Al Graps was born in Riga, Latvia, in 1931. He came to the U. S. in 1950. After finishing High school in Sioux Falls, South Dakota, he entered Augustana College, majoring in music. After one year he quit school and worked as a musician travelling around the midwest with several jazz bands. He then entered the Army for a three year hitch. After discharge he played in several of the night spots around Washington. This was real work so Al entered GW in 1956 to study engineering. While a student Al worked part time as a musician.

Al is married and has a two year old daughter. He is a national member of both the IRE and the AIEE and is an editor and advertising manager of the *Mecheleciv*.

This paper won the local IRE-AIEE Paper Contest, giving Al a chance to go to Philadelphia to compete in the District Two finals of the AIEE Student Paper Contest. Al won first place for GW over eight other competing universities.

# Signal-flow Graphs

**by AL GRAPS, E. E. '60**


## ABSTRACT

*The equations associated with a linear system are represented by a network of nodes and directed branches. The network, called a "signal-flow graph", serves essentially the same purpose as a matrix. All quantities pertinent in network analysis, such as gain, input and output impedances, etc., can be obtained from the flow graph, often with less effort than required in matrix evaluation. This paper deals with basic flow graph theory and application to two-terminal-pair networks. The flow graph method, however, is not limited to electrical networks, but is applicable to any linear system.*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## INTRODUCTION

A signal-flow graph is a graphical representation of equations of a linear system. It is merely another notation convention. The flow graph is constructed from a set of algebraic equations, and therefore contains the same amount of information as the algebraic equations. As the accompanying list of references shows, the signal-flow graph is relatively new in the field of electrical engineering. It was developed at the Massachusetts Institute of Technology by Dr. Samuel J. Mason, and the first publication of this method appeared in IRE Proceedings in 1953.

The advantage of the signal-flow graph lies in the fact that in many cases the answer to the problem can be obtained by mere inspection of the flow graph. In electrical engineering, its most useful application is in two-terminal-pair networks and feedback systems.

## BASIC PRINCIPLES OF SIGNAL-FLOW GRAPHS

The variables of an equation are represented by nodes, and the linear relationships between the variables are represented by directed branches. There is a strict distinction between dependent and independent variables. The signal

flow or branch direction is always from the independent variable to the dependent variable.

Given an equation:

$$x = ay$$

the flow graph representation of this equation is:

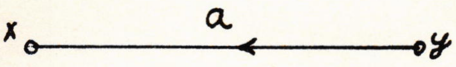



***Figure 1—Signal-flow graph of x=ay.***

If in the above equation, x is taken as the independent variable, the flow graph must be modified, according to the change in the equation rendering it y-explicit. i.e. $y = (1/a)x$. This process is known as flow graph inversion.

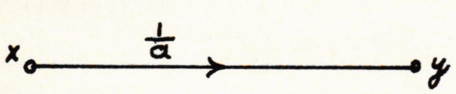



***Figure 2—Inverted flow graph of figure 1.***

In flow graphs the variables may be any quantities, voltage, current, force, charge, as long as the relationships between the variables are dimensionally correct. Thus, if in Fig. 1. x has the dimensions of current and y has the dimensions of voltage, then a must necessarily have dimensions of admittance. Or if x and y both have dimensions of voltage, then a must be dimensionless. Construction of a flow graph is accomplished by assembling all equations pertinent to a system, and then drawing the graph by linking the appropriate variables through their respective relationships.

Since the signal-flow graph technique is relatively new, the terminology concerning the flow graph operations is not uniform. The terminology used in this paper is a mixture of terms used by different authors, selected for brevity, unambiguity, and best fit, in the opinion of this author. The following terms will be used throughout this paper and their meaning will be best conveyed by inspecting the various details of the flow graph in Fig. 3.

Source—the independent variable, or a node with only exiting branches—$x_1$.

Sink —the dependent variable, or a node with only terminating branches—$x_6$.

Path —Continuous succession of branches, traversed in the indicated branch direction, along which no node is encountered more than once—$x_1$ to $x_2$ to $x_3$ to $x_4$ to $x_6$, and $x_1$ to $x_2$ to $x_5$ to $x_6$.

Branch-gain—the linear quantity relating one node to another regardless of its dimensions—$a_{12}$, $a_{23}$, etc.

Loop —a simple closed path, along which no node is encountered more than once per cycle—$x_4$ to $x_3$ to $x_4$.

Self-Loop—a closed path, starting and terminating on the same node without encountering any other nodes—$x_2$ to $x_2$.

Loop-gain—product of gains of branches in the closed loop—$a_{22}$, $a_{55}$, $a_{34}a_{43}$.

Since the primary use of flow graphs is in determining the input-output relationship, evaluation of the overall gain, source-to-sink, is accomplished by considering the various paths and loops in a flow graph. Overall gain may

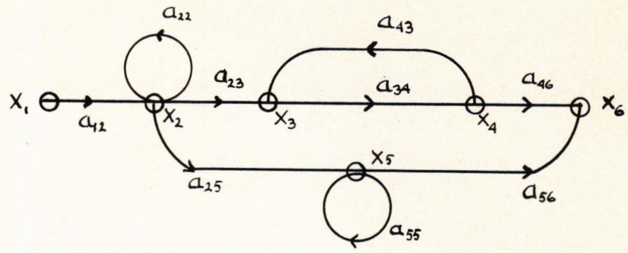



***Figure 3—A general flow graph.***

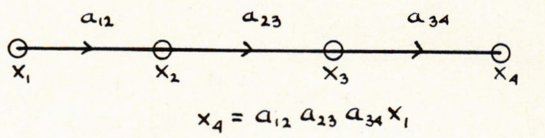



***Figure 4(a)—Series path. Total gain is product of branch gains.***

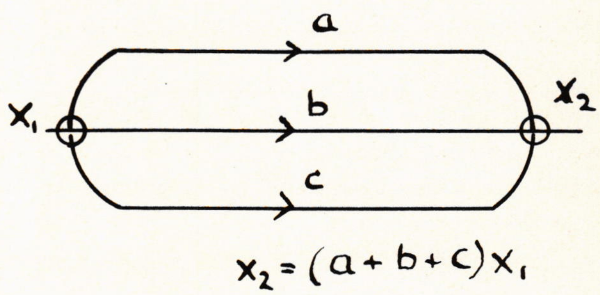



***Figure 4(b)—Parallel paths. Total gain is sum of branch gains.***

consist of path gains, loop gains, or both. The path gain is the product of all branch gains in that path. If there are several paths leading from source to sink, the overall path gain is the sum of the separate path gains. Fig. 4. If there is a loop touching a path, that path gain is modified by the factor $\dfrac{1}{1-g}$, where g represents the loop gain. This factor is included for each loop touching the particular path under consideration. Fig. 5(b).

If one considers the equations the flow graph is constructed from, the above rules are simply based on solutions of these equations. A different approach can also be used to demonstrate the origin of the $\dfrac{1}{1-g}$ factor. Considering a node with self-loop, Fig. 5(a), the self-loop can be imagined as infinite number of paths through the node. For example, a path could be going straight through the node without entering the loop—gain is unity. Another path could be passing through the loop—gain is a. Another path could be passing through the loop twice—gain is $a^2$, etc. Since all these paths are effectively in parallel,

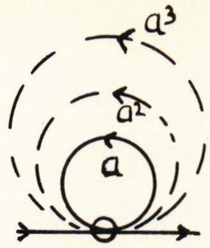
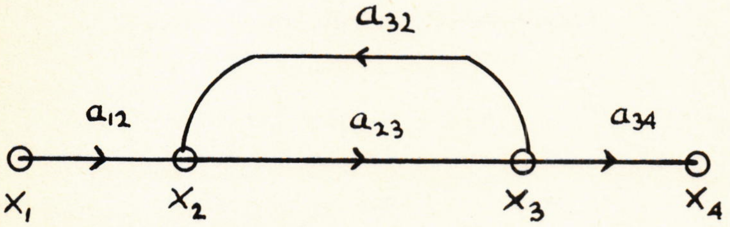



*Figure 5(a)—A node with self-loop.*




$$X_4 = \frac{a_{12}\, a_{23}\, a_{34}}{1 - a_{23}\, a_{32}}\, X_1$$

*Figure 5(b)—Gain of a flow graph with loop.*

the total gain would be $1 + a + a^2 + a^3 + a^4 \ldots$ This gain expression is the binomial expansion of $\dfrac{1}{1 - a}$, hence the modifying factor in the path gain. For a general loop, the term a encompasses all gains around the loop once, as shown in Fig. 5(b).

Often it is required that the flow graph be changed in order to obtain an input-output relationship between some other pair of variables, instead of the source and sink for which the flow graph was originally constructed. Rather than going back and rewriting the equations from which a new flow graph could be constructed for the desired variable pair, transformation of the original flow graph can be accomplished directly in order to give the desired source and sink. There are some limitations to this transformation process, however, which will be brought out in the following discussion. The transformation consists of inversion of paths and loops. This is merely a graphical manipulation of algebraic equations. To preserve a continuous graph, the only allowable inversions are the inversion of a path which originates as a source, and the inversion of a loop. Two kinds of inversions may be used: (1) an inversion in which the identity of the node is retained, but branch locations change, and (2) an inversion in which the branch location is preserved, but the node identity is lost. In the first case, to invert a branch $a_{jk}$ which runs from node j to node k, first move the tail of branch $a_{jk}$ from node j to node k, then move all branch noses at node k to the new position—node j. Replace gain of branch $a_{jk}$ by its reciprocal, and multiply by $-1/a_{jk}$ the gains of all other branches whose noses have been moved. To invert an entire path or a loop, simply invert all branches in that path or loop. This process is illustrated in Fig. 6. Branch location preserving inversions are illustrated in Fig. 7(a) and (b). It should be noted that in Fig. 7(b), $x_3'$ is not equal to $x_3$. Note also the change in sign of b.

It is possible to invert a path from an intermediate node to sink. In this process some nodes will disappear and the resulting flow graph will be of limited value, because not all of the effects of the system will now be shown. Fig. 7(c).

Inversion of loops between intermediate nodes is permissible, and no nodes are eliminated because of loop presence. This procedure is illustrated in Fig. 7(d) and follows the discussion for path inversion. Path and loop inversions are most essential in flow graph analysis technique. Herein lies its usefulness and one of the advantages over algebraic manipulations.

Fig. 8. illustrates flow graph reduction in order to evaluate the overall gain. The reduction is simply application of the rules for path and loop gains discussed previously. For complex signal-flow graphs, the step-by-step reduction becomes tedious. A general gain formula has been developed by S. J. Mason (see references), which yields the overall gain expression without performing any reduction operations. This is the second advantage of signal-flow graphs. The general gain formula is:

$$G = \frac{G_k\ \Delta_k}{\Delta}$$

Where: $G$ =the overall gain
$G_k$=the gain of the $k^{th}$ path
$\Delta$ =1—(sum of all individual loop gains)
+(sum of the gain products of all possible combinations of 2 non-touching loops)
—(sum of the gain products of all possible combinations of 3 non-touching loops) + . . .
$\Delta_k$=the value of $\Delta$ for that part of the graph not touching the $k^{th}$ path.

Application of the general gain formula is shown in Fig. 9.

## APPLICATION OF SIGNAL FLOW GRAPHS

The common equations for two-terminal-pair networks, together with their flow graph representations are given in Fig. 10. These equations and consequently the flow graphs in any one given set of parameters completely describe the characteristics of the network. If one set of parameters is known, by path inversion it is possible to obtain any other set of parameters in terms of the given parameters. Heretofore, this process was carried out with operations of matrix determinants, however, flow graphs yield the results more rapidly. Illustration of this flow graph application is shown in Fig. 11.

Suppose that it is desired to know how a network's parameters change, when a new terminal pair is selected as the input. If the known network parameters are A parameters for the input and output terminals as shown in Fig. 12(a), it is now desired to know the parameters for the new input-output terminals as shown in Fig. 12(b). This type of analysis is often useful in determination of maximum input impedance available from a given device, or maximum gain, minimum or maximum feedback, etc. Flow

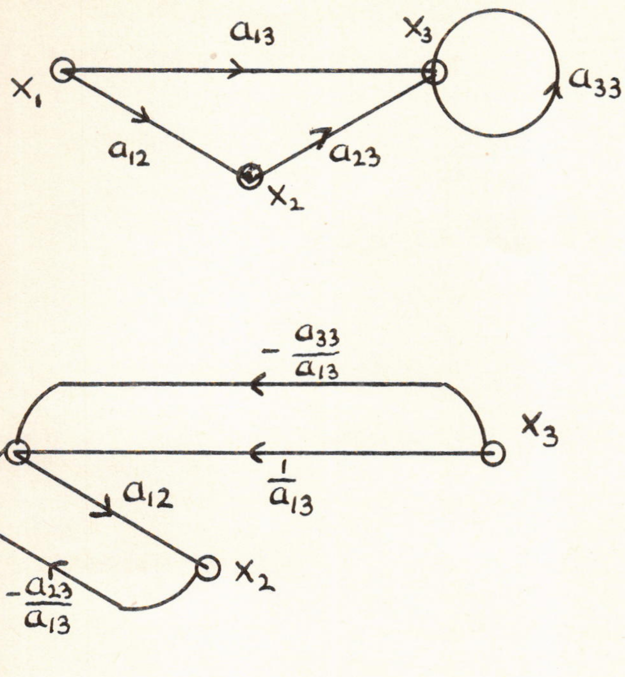



*Figure 6—Inversion of the path $x_1$ to $x_3$. Node identity is preserved.*

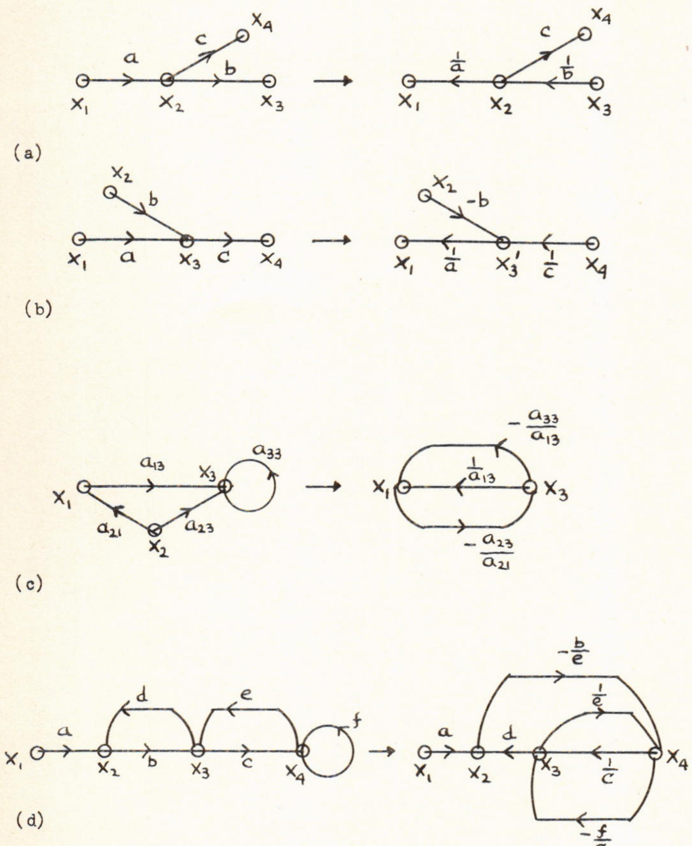
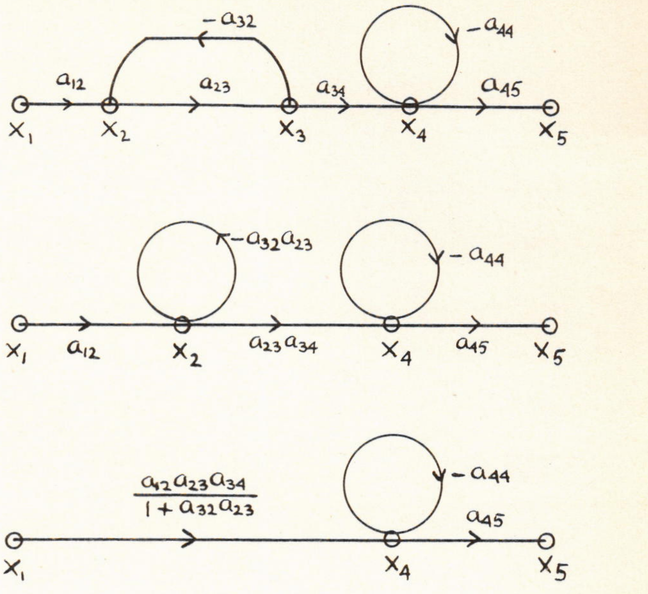
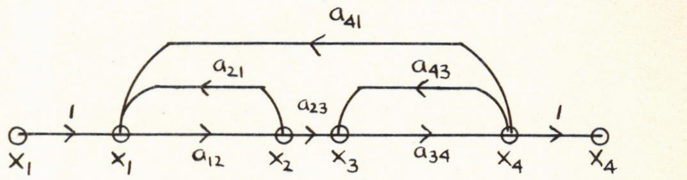



*Figure 7—Various path inversions. (a) and (b) Preservation of branch locations. (c) Inversion of path not originating at a source. (d) Inversion of loops between nodes which are neither sources nor sinks.*




$$\frac{x_5}{x_1} = \frac{a_{12}\,a_{23}\,a_{34}\,a_{45}}{(1+a_{32}a_{23})(1+a_{44})}$$

*Figure 8—An example in flow graph reduction.*




$$G = \frac{x_4}{x_1} = \sum \frac{G_k \Delta_k}{\Delta}\,; \qquad G_1 = a_{12}a_{23}a_{34}\,; \quad \Delta_1 = 1$$

$$= \frac{(a_{12}\,a_{23}\,a_{34})(1)}{1-(a_{12}a_{21}+a_{34}a_{43}+a_{41}a_{12}a_{23}a_{34})+(a_{12}a_{21}\,a_{34}\,a_{43})}$$

*Figure 9—Application of general gain formula.*

graph procedure is as follows: (1) the given flow graph for the given parameters is placed in the center; (2) the new nodes are constructed around the perimeter, as the voltages and currents of the rotated network. (3) From this circuit diagram, relationships are established between original and new voltages and currents. (4) From these relationships appropriate connections are made between the flow graph and the new nodes, and (5) the new parameters evaluated as shown in Fig. 12 (c).

When two or more two-terminal-pair networks are connected, whether in parallel-parallel, cascade, series-parallel, etc., flow graphs provide convenient means for evaluation of the new, combined parameters. According to matrix methods, cascade connection of two-terminal-pair networks results in product of their respective A-matrices. Parallel-parallel network connection results in addition of their respective Y-matrices, etc. This requires that for each type of connection the network parameters are in the proper form. Although, using flow graph technique, it is possible to change from one set of parameters to another set with

$$E_1 = Z_{11} I_1 + Z_{12} I_2$$
$$E_2 = Z_{21} I_1 + Z_{22} I_2$$

$$I_1 = Y_{11} E_1 + Y_{12} E_2$$
$$I_2 = Y_{21} E_1 + Y_{22} E_2$$

$$E_1 = A E_2 + B I_2$$
$$I_1 = C E_2 + D I_2$$

$$E_1 = H_{11} I_1 + H_{12} E_2$$
$$I_2 = H_{21} I_1 + H_{22} E_2$$

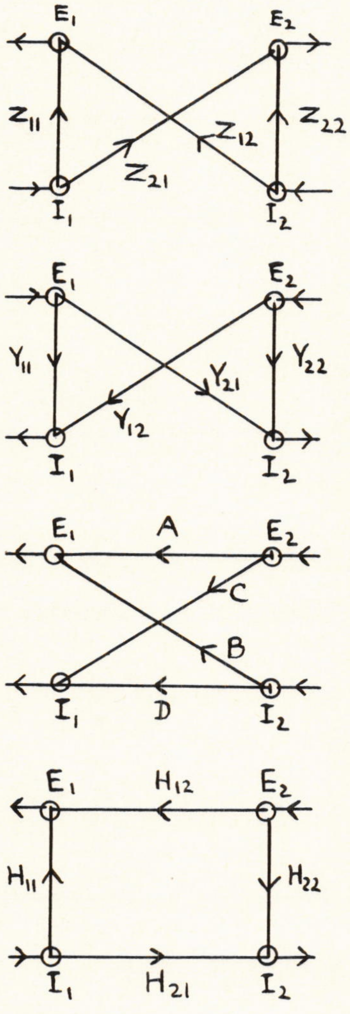



***Figure 10—Common two-terminal-pair network equations and their flow graph representations.***

considerable ease, as shown in Fig. 11., it is not necessary to perform the transformation. Connecting two or more two-terminal-pair networks in any manner whatsoever, consists of connecting their flow graphs. All that is required is that the flow graphs be compatible, i.e., connections may be made between source and non-source nodes; never source to source or sink to sink. If the flow graphs are not compatible, they must be made compatible by appropriate path inversion. Of course, the flow graph connection must also be in accordance with the relationships among the voltages and currents of the different networks. As in the example of network rotation, the connected flow graphs are placed in the center, and the nodes representing the terminal voltages and currents of the combination are placed around the perimeter, and then linked to the flow graphs through branches representing voltage and current relationships between the networks and the new terminals. The combination's parameters are then obtained as shown in Fig. 13.

Finally, flow graph technique application is shown in analysis of an actual circuit. The circuit is a grounded-base

$$E_1 = Z_{11} I_1 + Z_{12} I_2$$
$$E_2 = Z_{21} I_1 + Z_{22} I_2$$

$$Y_{11} = \frac{Z_{22}}{Z_{11}Z_{22} - Z_{12}Z_{21}} \; ; \quad Y_{12} = \frac{-Z_{12}}{Z_{11}Z_{22} - Z_{12}Z_{21}} \; ;$$
$$Y_{21} = \frac{-Z_{21}}{Z_{11}Z_{22} - Z_{12}Z_{21}} \; ; \quad Y_{22} = \frac{Z_{11}}{Z_{11}Z_{22} - Z_{12}Z_{21}} \; ;$$

$$A = \frac{Z_{11}}{Z_{21}} \; ; \quad B = \frac{-(Z_{11}Z_{22} - Z_{12}Z_{21})}{Z_{21}} \; ;$$
$$C = \frac{1}{Z_{21}} \; ; \quad D = \frac{-Z_{22}}{Z_{21}} \; ;$$

$$H_{11} = \frac{Z_{11}Z_{22} - Z_{12}Z_{21}}{Z_{22}} \; ; \quad H_{12} = \frac{Z_{12}}{Z_{22}} \; ;$$
$$H_{21} = \frac{-Z_{21}}{Z_{22}} \; ; \quad H_{22} = \frac{1}{Z_{22}}$$

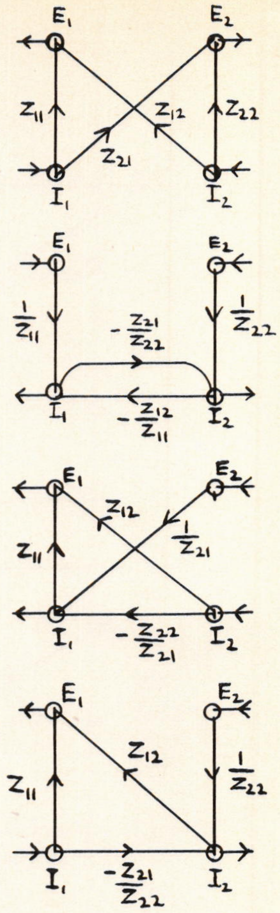
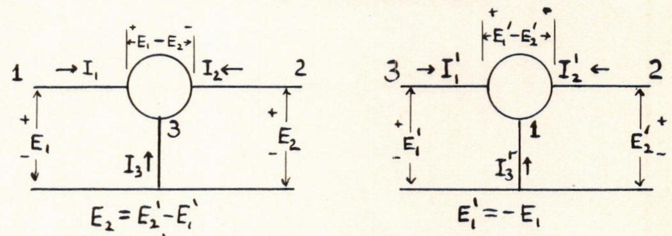
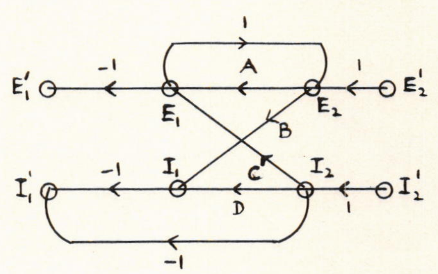



***Figure 11 — Transformation of Z-parameter flow graph to Y, A, and H-parameter flow graphs in terms of Z-parameters.***



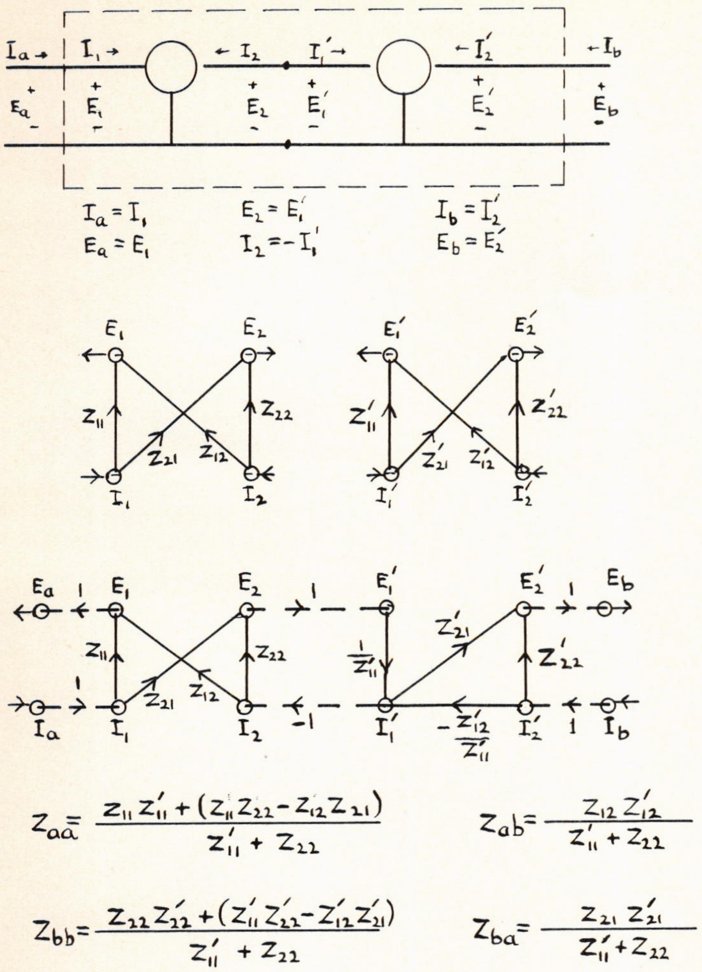

$$E_2 = E_2' - E_1' \qquad E_1' = -E_1$$
$$I_2 = I_2' \qquad I_1' = -I_1 - I_2$$




$$A' = \left.\frac{E_1'}{E_2'}\right|_{I_2'=0} = -A\left(\frac{1}{1-A}\right) \qquad B' = \left.\frac{E_1'}{I_2'}\right|_{E_2'=0} = -B\left(\frac{1}{1-A}\right)$$

$$C' = \left.\frac{I_1'}{E_2'}\right|_{I_2'=0} = -C\left(\frac{1}{1-A}\right) \qquad D' = \left.\frac{I_1'}{I_2'}\right|_{E_2'=0} = -D - \left(\frac{BC}{1-A}\right)$$

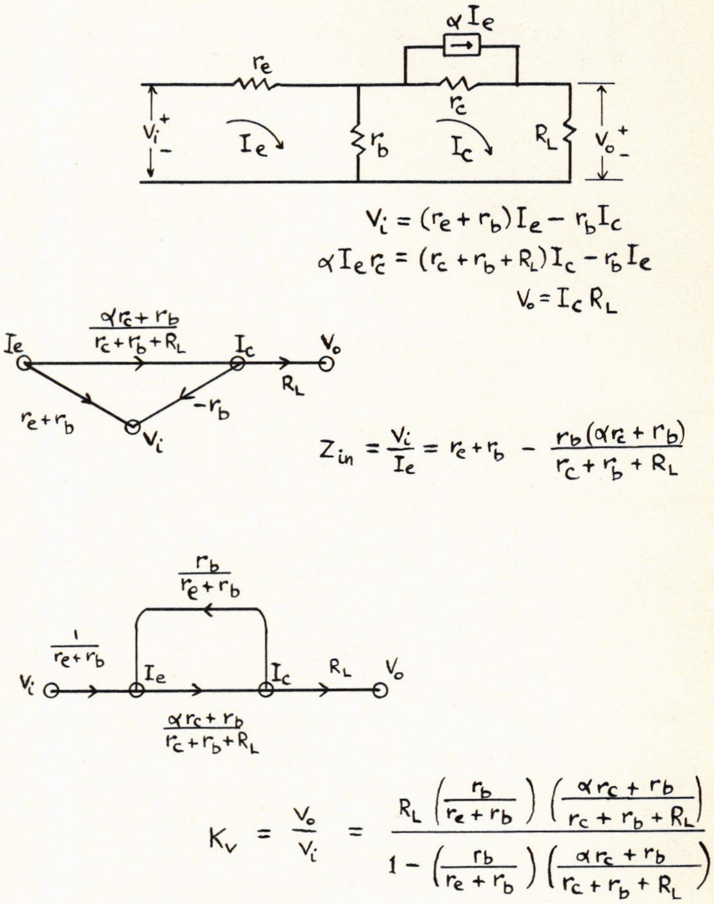
***Figure 12—Rotation of terminals of a two-terminal-pair network, and new parameter evaluation in terms of the original parameters.***




$$Z_{aa} = \frac{Z_{11} Z_{11}' + (Z_{11} Z_{22} - Z_{12} Z_{21})}{Z_{11}' + Z_{22}} \qquad Z_{ab} = \frac{Z_{12} Z_{12}'}{Z_{11}' + Z_{22}}$$

$$Z_{bb} = \frac{Z_{22} Z_{22}' + (Z_{11}' Z_{22}' - Z_{12}' Z_{21}')}{Z_{11}' + Z_{22}} \qquad Z_{ba} = \frac{Z_{21} Z_{21}'}{Z_{11}' + Z_{22}}$$

***Figure 13—Cascade of two two-terminal-pair networks. Evaluation of Z-parameters of the combination directly in terms of the given Z-parameters.***




$$V_i = (r_e + r_b) I_e - r_b I_c$$

$$\alpha I_e r_c = (r_c + r_b + R_L) I_c - r_b I_e$$

$$V_o = I_c R_L$$

$$Z_{in} = \frac{V_i}{I_e} = r_e + r_b - \frac{r_b(\alpha r_c + r_b)}{r_c + r_b + R_L}$$

$$K_v = \frac{V_o}{V_i} = \frac{R_L \left(\frac{r_b}{r_e + r_b}\right)\left(\frac{\alpha r_c + r_b}{r_c + r_b + R_L}\right)}{1 - \left(\frac{r_b}{r_e + r_b}\right)\left(\frac{\alpha r_c + r_b}{r_c + r_b + R_L}\right)}$$

***Figure 14—Evaluation of input impedance and gain of a grounded-base transistor with load.***

transistor amplifier equivalent circuit. From loop equations for this circuit a flow graph is constructed, and it is seen in Fig. 14. that the flow graph is in proper form for input impedance or admittance evaluation. In order to obtain voltage gain, the flow graph must be modified to give a source-to-sink path between $V_i$ and $V_o$. Node Preserving inversion is to be used, since branch preserving inversion would change node $V_i$ to some other quantity, rendering the flow graph useless for voltage gain evaluation. Inverting the branch $I_e$ to $V_i$, puts the flow graph in proper form and the voltage gain is easily obtained.

It may be observed at this point that the overall gain expressions always appear in unfamiliar forms, often complex fractions, except in cases where the general gain formula is applied. However, expressions obtained by flow graph method in circuit analysis are the same as obtained from the same circuit by conventional circuit analysis, and some algebraic manipulation will prove this to be so.

## CONCLUSION

The preceding discussion served as an introduction to signal-flow graph technique for solving problems in linear systems. The flow graph has the advantage of showing visually the relationships among the variables in the system. Further advantages lie in the fact that all quantities of interest in network analysis can be obtained from the flow graph with minimum effort. It is not implied, however, that all problems can be solved with greater ease by using flow graph charts. Although the only restriction on the use of flow graphs is that the equations be linear, some types of problems yield themselves better to application of flow graphs than other types of problems. The method to use in any analysis is the method that will give the correct answer in the shortest amount of time. In electrical engineering, the two-terminal-pair network is ideally suited for flow graph type of analysis.

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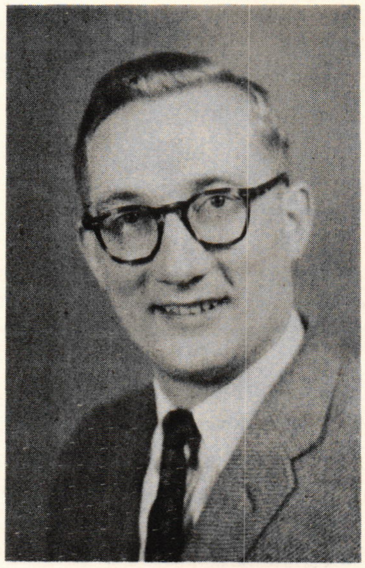
# Three-Level Solid-State Masers



by LEON H. SIBUL, E. E. '60

## INTRODUCTION

Maser technology has developed beyond initial research stages to the point where masers are used in practical circuits. For this reason it is important for an engineer to have some familiarity with the physical principles and circuits of masers. Different types of masers, their uses, their advantages and disadvantages will be discussed first; then the most promising three-level solid-state maser will be treated in some detail.

## MASERS IN GENERAL

The word "maser" is derived from the sentence "microwave amplification by stimulated emission of radiation."

Masers can be divided into two main categories: gas and solid-state masers. Of the gas masers the ammonia beam maser is well known as one of the most precise frequency standards in existence. The most successful solid-state masers use paramagnetic crystal for their active elements. Of the paramagnetic masers there are two-level and three-level masers. Chief promise of the two-level maser is generation of relatively high pulsed power at the millimeter wavelengths. From the engineers' standpoint the three-level solid-state maser is most interesting; it is a continuously operating low-noise microwave amplifier. It can be used as an easily tunable broad-band amplifier.[1]

The operating conditions of the three-level solid-state maser are a nuisance since it must be held at a temperature near absolute zero. However, this great disadvantage is also a unique advantage: no other amplifier operates at liquid helium temperatures.[2] Because of such low-temperature operation the noise temperature of a maser amplifier is in the order of 2° Kelvin.[3] For this reason the maser amplifier makes it possible to detect signals heretofore lost in the background noise.

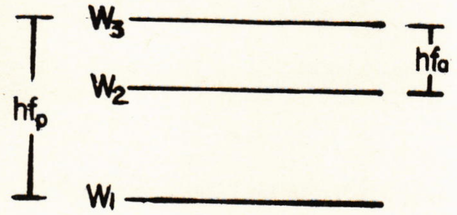
The three-level maser's low noise characteristics lead to its utilization in radio astronomy, scatter communication, missile and satellite tracking, and paramagnetic studies.[4] Because three-level masers hold greatest promise in engineering applications, this paper reviews their physical principles and typical circuits.

## PHYSICAL PRINCIPLES OF THREE-LEVEL SOLID-STATE MASER

When a paramagnetic crystal is placed in a magnetic field, the magnetic atoms assume only certain energy states. In a three-level maser there are three energy states, depicted

[1] H. E. D. Scovile, "Three-level solid-state maser," IRE Transactions on Microwave Theory and Techniques, Volume MTT-6, January, 1958, pp 29-38.
[2] J. R. Singer, "Masers," John Wiley & Sons, Inc., 1959, p. 3.
[3] A. L. McWhorter, F. R. Arams, "System-noise measurement of a solid-state maser," Proc. IRE, vol 46, May 58, pp 913-914.
[4] Singer, op. cit., p. 5.

in Figure 1. Under normal equilibrium conditions more atoms are in the lower energy states than in the upper states. To obtain maser action atoms are raised from the




$$W_3 - W_1 = h\,f_p$$
$$W_3 - W_2 = h\,f_a$$

$f_a$ Amplifying frequency
$f_p$ Pumping frequency
h Planck's constant 6.623 $10^{-27}$erg-sec.

***Figure 1. Energy levels of three-level masers.***

lowest energy level ($W_1$) to the highest energy level ($W_3$) by the energy of the pumping frequency. The frequency that is to be amplified stimulates the atoms to fall from $W_3$ to $W_2$, thus causing the crystal to give up energy to the electromagnetic field. This energy is the amplified signal.

In the following sections these physical processes are discussed in greater detail.

### *1. Paramagnetism and Magnetic Moments*

To understand the physical principles of the three-level solid-state maser one must have a general understanding of paramagnetism.

Paramagnetism is a property of atoms and molecules that depends on the arrangement of their electrons. Atoms and molecules that have an odd number of electrons, or have partly filled inner shells, exhibit paramagnetic properties.[5] Paramagnetism results from magnetic dipoles that are generated by the spin of the electrons or by the rotation of electrons in their orbits. If atoms have an even number of electrons, and if all the inner shells are filled, the effects of these dipoles cancel and the atoms show no paramagnetic properties. Elements belonging to the iron, palladium, platinum, rare earth, and transuranic groups are paramagnetic. In maser application only the iron and rare earth groups are promising.[6] From these groups the ions of elements Ni, Cr, Fe, and Gd are useful.[7]

Next some relations useful in understanding paramagnetism are presented.

The magnetic moment of the spinning electron has the magnitude of one Bohr magneton:[8] (See "List of Symbols.")

$$\mu = \frac{eh}{4\pi mc}$$

Study of atomic spectra indicates that the spin must have the value [9]

$$s = \frac{1}{2}\,\frac{h}{2\pi} = \frac{1}{2}\hbar$$

Thus the spin quantum number has values of $\pm\frac{1}{2}$. The total spin quantum number S is given by the expression:

$$S = \sum s$$

The magnetic moment owing to angular momentum of the orbiting electron is:

$$\mathcal{M}_L = -\frac{e}{2mc}L$$

where L is the resultant orbital momentum. The resultant total momentum quantum number of the atom is formed from L and S:

$$\bar{L} + \bar{S} = \bar{J}$$

In the general case, the magnetic moment of the atom is given by

$$\mathcal{M} = \sqrt{J(J+1)}\,g\mu$$

where $\mu$ is the Bohr magneton, and g is the Landé factor, given by: [10]

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$$

Splitting of energy states in the magnetic field was discovered by Zeeman in 1896. Spectroscopy has shown that a quantum number is needed that specifies the orientation of one of the angular momenta quantum numbers with respect to an external electric or magnetic field.[11] This may be called the orientation quantum number M.

According to the quantum theory only those angles between magnetic field and magnetic dipoles of the atom

[5] C. Kittel, "Introduction to Solid State Physics," John Wiley & Sons, Inc., Second Edition, 1959, p. 212.
[6] Scovil, op. cit., p. 33.
[7] Ibid.

[8] W. Finkelnburg, "Atomic Physics," McGraw-Hill, 1950 p. 143.
[9] Finkelnburg, op. cit., p. 143.
[10] Finkelnburg, op. cit., pp. 152-156.
[11] Ibid., pp. 155-156.

are allowed for which the components of J in the field direction are integral or half-integral multiples of $\eta$, depending upon whether J itself is integral or half-integral.[12] Thus, the possible values of M are:

$$M = J, J - 1, J - 2, \ldots\ldots -J$$

Therefore, there are $2J + 1$ possible values of M.

If a small bar magnet with a magnetic moment $M$ is placed in a magnetic field of strength H, then the magnet has potential energy

$$U = \bar{M}\bar{H} = M_H H$$

where $M_H$ is the component of $M$ in the direction of the field. It follows that the splitting of the energy levels of a paramagnetic material in a magnetic field is given by:

$$\Delta W = M_H H = \mu g(L, S, J) H M$$

For $J = 1$, M can take on three different values giving three energy levels needed for the three-level maser. Since change of energy is proportional to H, H can be used to tune the amplifier.

### 2. *Inversion*

One of the central conclusions of statistical mechanics is that in thermal equilibrium the probability of finding a system in state i is proportional to $e^{-W_i/kT}$, where $W_i$ is the energy of state i.[13] Let N be the total number of atoms in the crystal, and $N_1$, $N_2$, $N_3$, the number of atoms at each state respectively. Then

$$(N_1 + N_2 + N_3) = N \qquad \text{(constant)}$$

From the above relations:

$$N_3 = N_1 e^{\frac{-(W3-W1)}{kT}} = N_1 e^{\frac{-hf_p}{kT}}$$

$$N_2 = N_1 e^{\frac{-(W2-W0)}{kT}} = N_1 e^{\frac{-hf_a}{kT}}$$

Thus for normal thermal equilibrium there are more electrons in lower energy states than in higher states. For maser amplification, the probability for the transition from 3 to 2 must be greater than the probability for transition from 2 to 3. Probability of transition from one energy level to the other is proportional to the difference of population of the two energy levels. The most probable transition takes place from greater population to smaller population. For this reason the normal thermal equilibrium populations must be inverted for amplification. This is accomplished by the pumping frequency. Sufficient power input must be provided at the pumping frequency to overwhelm the thermal processes tending to restore the levels of normal Boltzman distribution. In an actual maser anywhere from 1 milliwatt to 240 milliwatts of pumping power has been used.[14]

### 3. *Power Output*

Power output of a maser operating as an amplifier between energy levels 3 and 2 is equal to the energy difference between these levels ($hf_a$) times the probability of transition. Probability of transition is equal to the difference in the populations times the probability of stimulated emission per second, $p_{32}$.

$$P_{out} = (N_3 - N_2)\, hf_a P_{32}$$ [15]

The population $N_3$ must be greater than $N_2$ for positive power output. $p_{32}$ is proportional to the signal input power. Thus, power amplification can be achieved. Output power of 4.0 microwatts has been obtained with $f_a = 2800$ Mc and $f_p = 6600$ Mc.[16] Higher output has been produced at different frequencies and pumping powers.

## EQUIPMENT AND CIRCUITS

Because paramagnetic energy is small compared to thermal energy, solid-state masers must be operated at liquid helium temperatures, usually between 1° to 2° Kelvin. The paramagnetic crystal and its cavity are usually immersed in liquid helium. The cavity may or may not be sealed off from the liquid helium. Liquid helium requires a double Dewar system. The outer Dewar is filled with liquid nitrogen.

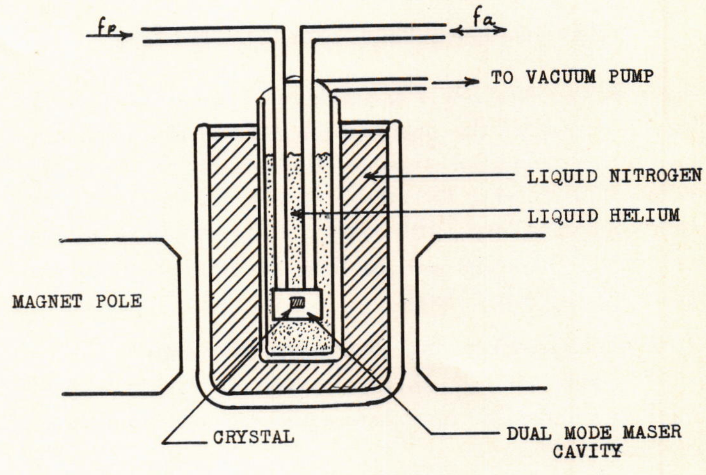



***Figure 2. Physical arrangement of a three-level maser***
Singer, op.cit., p. 120

To obtain the desired energy-level splitting, the maser cavity, in its double Dewar, is placed in a homogeneous constant magnetic field. It is necessary to regulate the magnet current to about one part in $10^5$ to avoid operating frequency drifts.[17]

The crystal is mounted in the cavity at the rf magnetic field maximum. This condition must be satisfied for both pumping and signal frequencies. The design of a cavity with two resonant frequencies is very difficult, and usually

[12] Ibid., p. 156.
[13] R. W. Gurney, "Introduction to Statistical Mechanics", McGraw Hill, 1949, p. 40.

[14] Singer, op. cit., p. 100.
[15] Ibid., p. 93.
[16] Ibid., p. 94.
[17] Ibid., 116.

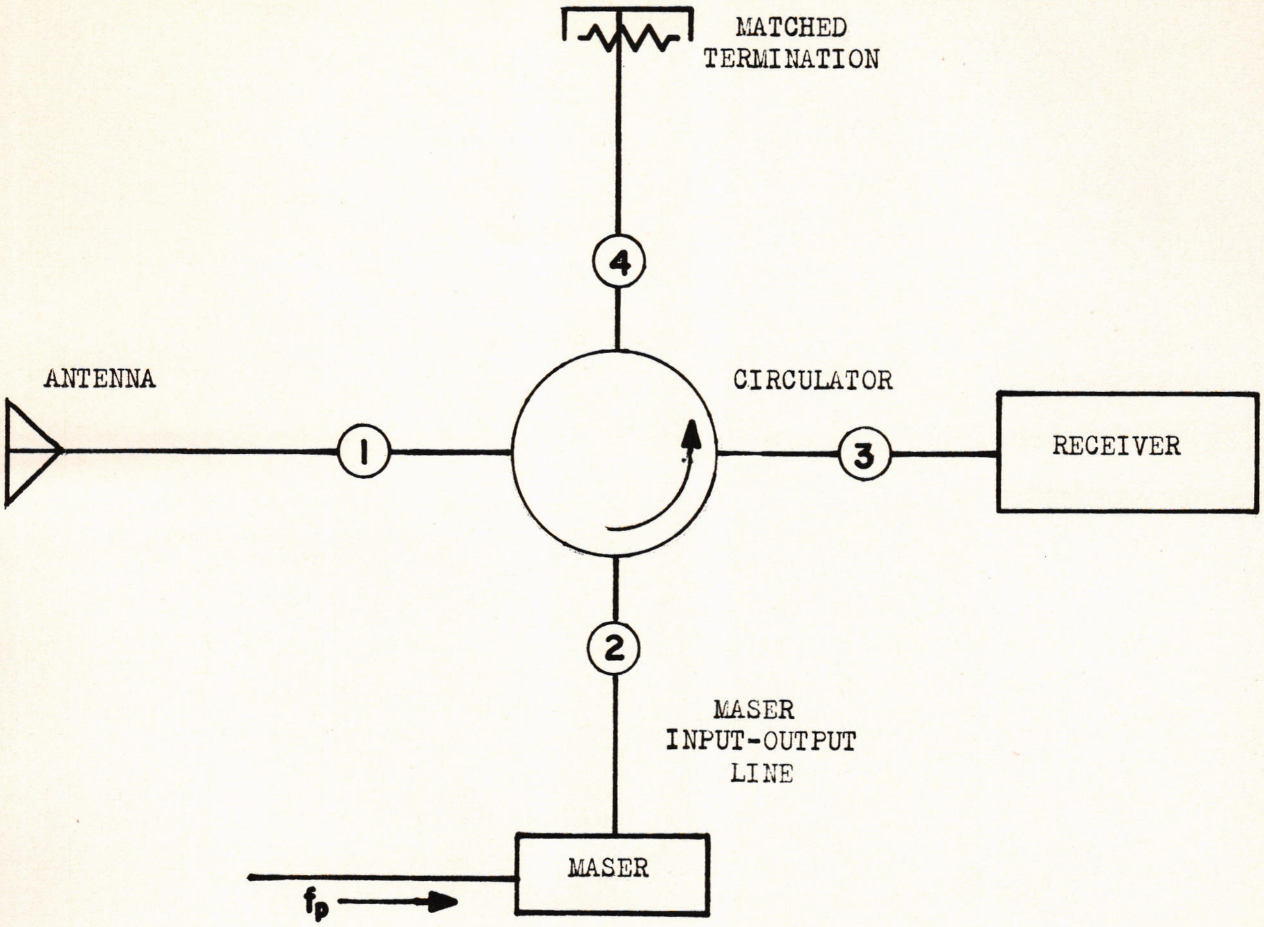



***Figure 3. Maser circuit using a circulator***
Armas, op. cit., p. 912

some compromises must be made. Rf fields are perpendicular to the constant field. A circuit diagram for the three-level maser is shown in Figure 3.

As indicated on the diagram, the maser, is a single port device. The low-level signal enters and the amplified signal leaves by the same port. By connecting a circulator to the single-port maser, maximum gain-bandwidth is obtained; at the same time noise radiated from the receiver is isolated from the maser. The input signal is coupled by the circulator to the receiver.[18] Standing wave ratio in the load (seen by the maser) must be low for stable operation. Other circuit arrangements have been investigated, but this arrangement gives highest gain-bandwidth product without sacrifice in noise figure.[19]

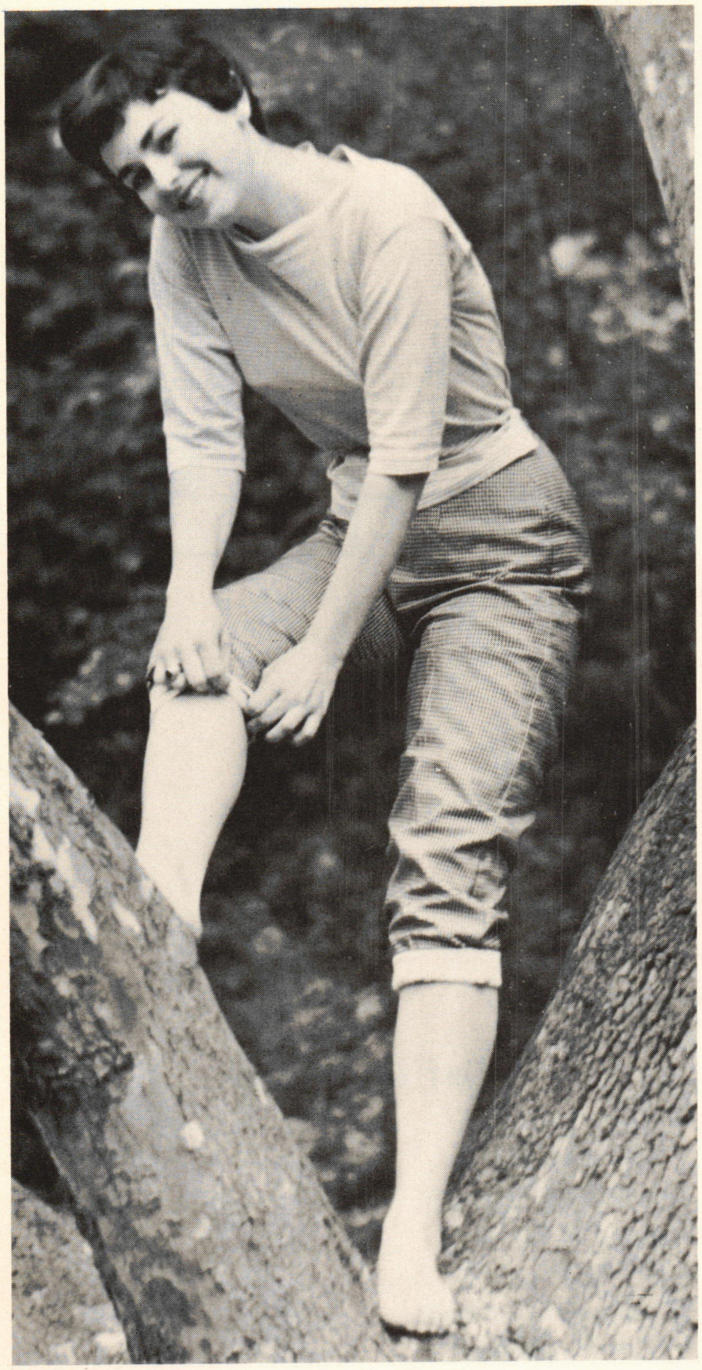
New developments can be expected, both in maser circuits and in paramagnetic materials. Circuits must be improved to take full advantage of the maser's low noise characteristics. Better paramagnetic materials must be found to allow masers to be operated at somewhat higher temperatures without sacrifice in noise figure. These and other problems of solid-state devices represent an exciting challenge for engineers and physicists.

[18] F. R. Arams, and G. Krayer, "Design considerations for circulator maser systems," Pro. IRE, vol. 46, May 58 pp. 912-913.

[19] A. E. Siegman, "Gain bandwith and noise in maser amplifiers," Proc. IRE, vol. 45, December 57, pp. 1737-1738.

## LIST OF SYMBOLS

- $c$ velocity of light
- $e$ charge of electron
- $f_a$ amplifying frequency
- $f_p$ pumping freqency
- $g$ Landé factor
- $H$ magnetic field intensity
- $h$ Planck's constant
- $\eta$ $h/2\pi$
- $J$ resultant total momentum quantum number
- $k$ Boltzmann's constant
- $L$ total orbital momentum quantum number
- $M$ orientation quantum number
- $m$ mass of electron
- $\mathcal{M}$ magnetic moment
- $\mu$ Bohr magneton
- $N$ number of atoms
- $P$ power
- $p$ probability
- $S$ total spin quantum number
- $s$ spin quantum number
- $T$ temperature in Kelvin
- $W$ energy



# MECH MISS . . .

Our May Mech Miss is pretty Marjorie Gray. Margie is a part time student here, since she works full time in the school's treasurer's office. She is a sophomore majoring in accounting.

Margie is a real Southern Belle from North Carolina. After graduation from High School, she attended an Air Line School in Hartford for about a year before coming to GW.

# What's New?

**Edited by NICK KOPULOS**

**Nuclear Core for N. S. Savannah**

The nuclear power core which will some day drive the N. S. "Savannah," the world's first atom-powered merchant ship, has achieved a sustained chain reaction. It is believed to be the first propulsion reactor power core known to achieve criticality before installation.

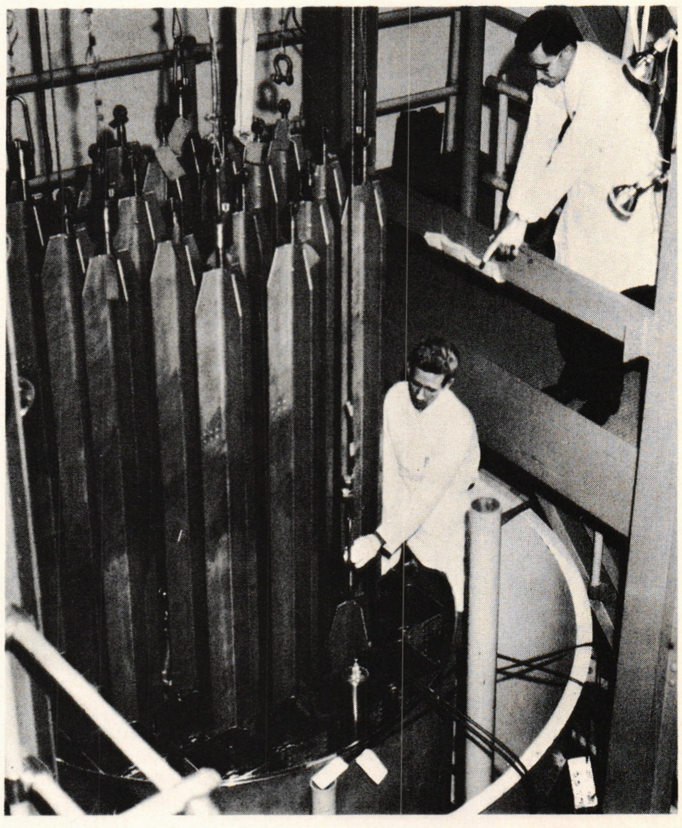
The test confirmed nuclear design and engineering calculations, and provided first hand experience for the safe installation of the core aboard the "Savannah."

Weighing more than 15 tons, the core is made up of 32 fuel elements containing 4.2 and 4.6 per cent enriched uranium, 21 control rods, and internal "hardware." It contains the heaviest known quantity of uranium ever used in a commercial critical experiment laboratory test.

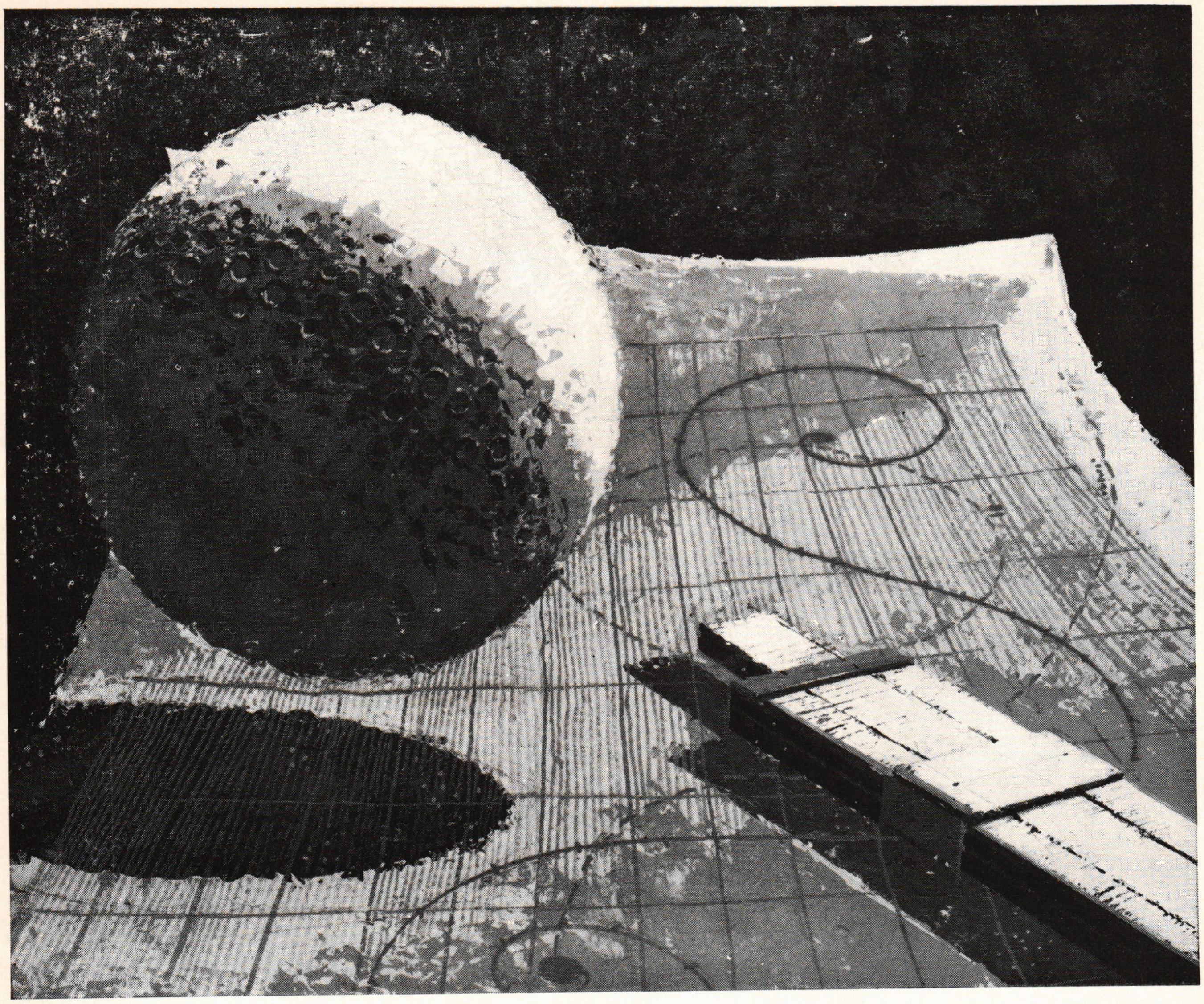
The core was tested in a tank 9 feet in diameter and 17 feet high, filled with more than 10,000 gallons of de-ionized, or purified, water. Each fuel element weighs about 800 pounds and contains 164 stainless steel rods loaded with uranium pellets. Each of the 21 control rods, which are used to regulate the reactivity and to compensate for fuel consumption within the reactor, weighs 225 pounds.

The "Savannah" is being built under President Eisenhower's "Atoms for Peace" program by the U. S. Atomic Energy Commission and Maritime Administration.

The vessel was launched last July 21, after it was christened by Mamie Eisenhower.



***Assembly of the nuclear reactor core of the N. S. Savannah.***



# What happens to your career... after you join Western Electric?

You'll quickly find the answer is *growth*. The signs of progress — and opportunity — are clear, whether your chosen field is engineering or other professional work. There is the day-to-day challenge that keeps you on your toes. There are new products, new areas for activity, continuing growth, and progressive programs of research and development.

For here telephone science is applied to two major fields — manufacture and supply for the Bell Telephone System, and the vitally important areas of defense communications and missile projects.

You'll find that Western Electric is career-minded... and *you*-minded! Progress is as rapid as your own individual skills permit. We estimate that 8,000 supervisory jobs will open in the next ten years — the majority to be filled by engineers. There will be corresponding opportunities for career building within research and engineering. Western Electric maintains its own full-time all-expenses-paid engineering training program. And our tuition refund plan also helps you move ahead in your chosen field.

**Opportunities exist for electrical, mechanical, industrial, civil and chemical engineers, as well as in the physical sciences. For more information get your copy of *Consider a Career at Western Electric* from your Placement Officer. Or write College Relations, Room 200D, Western Electric Company, 195 Broadway, New York 7, N. Y. Be sure to arrange for a Western Electric interview when the Bell System team visits your campus.**

**Western Electric**

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

Principal manufacturing locations at Chicago, Ill.; Kearny, N. J.; Baltimore, Md.; Indianapolis, Ind.; Allentown and Laureldale, Pa.; Burlington, Greensboro and Winston-Salem, N. C.; Buffalo, N. Y.; North Andover, Mass.; Lincoln and Omaha, Neb.; Kansas City, Mo.; Columbus, Ohio; Oklahoma City, Okla.; Engineering Research Center, Princeton, N. J.; Teletype Corp., Chicago 14, Ill. and Little Rock, Ark. Also W. E. distribution centers in 32 cities and installation headquarters in 16 cities. General headquarters: 195 Broadway, New York 7, N.Y

## TINY MAGNET

A tiny permanent magnet, no bigger than a half dollar, is helping to guide the Sparrow III missile to its target by supplying the power output used in the guidance system of the missile.

The Sparrow III is the Navy's air-to-air missile that can seek out an enemy aircraft and down it, adjusting its aim as it seeks out its prey.

Attached to the rotor of the turbine-powered synchronous generator, the small magnet can generate up to 35 watts of power for the missile's guidance system. In spite of the high degree of sophistication, the reliability of the missile has been excellent. The missile has been tested more than 200 times with a high degree of hits on aircraft drones.

All magnets are tested prior to their being used in the Sparrow III, and are again tested when in place on the guidance system. These tests consist of proper wattage output, proper balance while under load, a rugged vibration test, and a temperature test—from a —30 degrees F to a +200 degrees F.

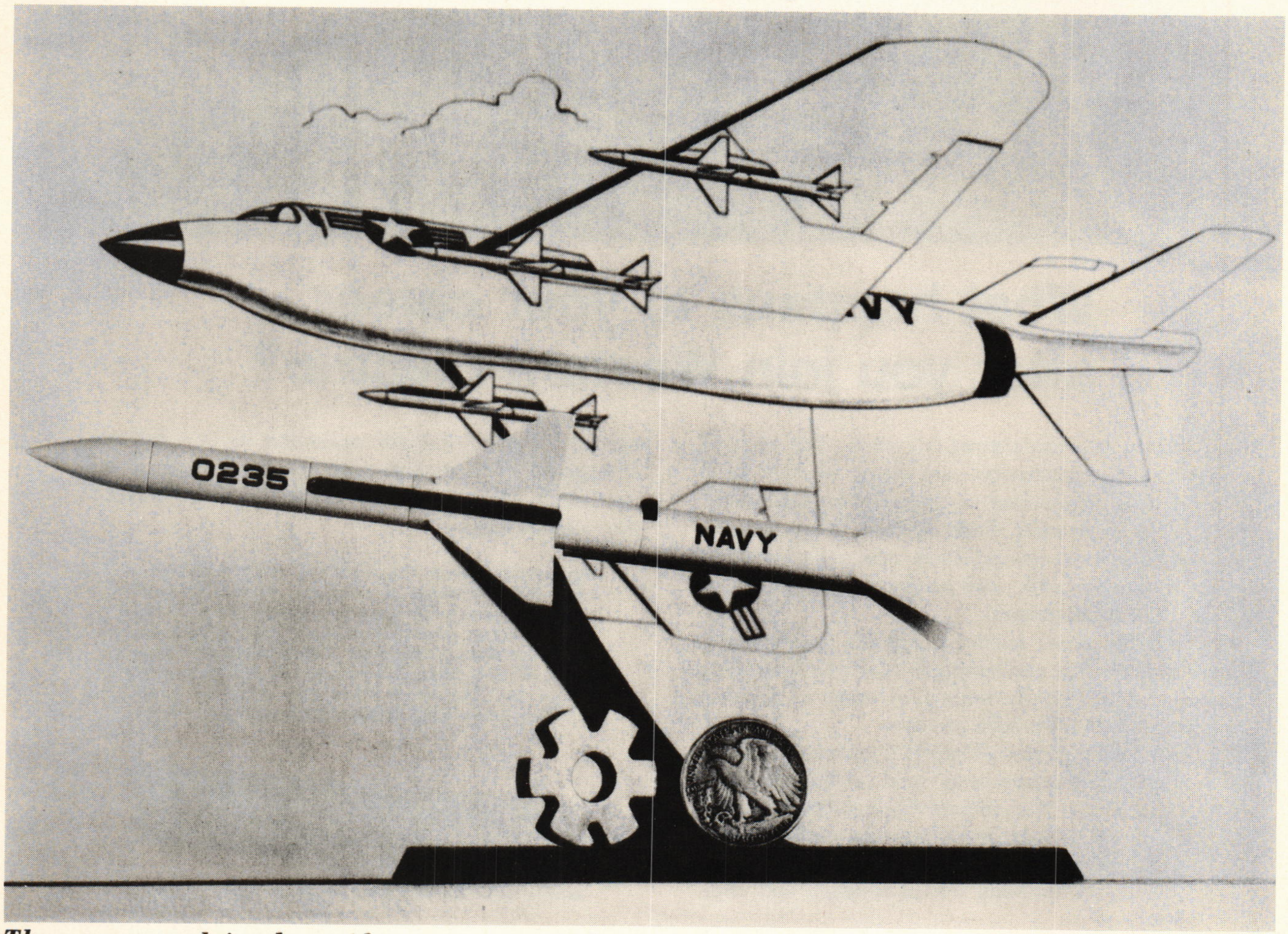
The Sparrow III is a solid-fuel missile about 12-feet long, with a body 8-inches in diameter and weighing about 350 pounds.

## SILICONE STADIUM

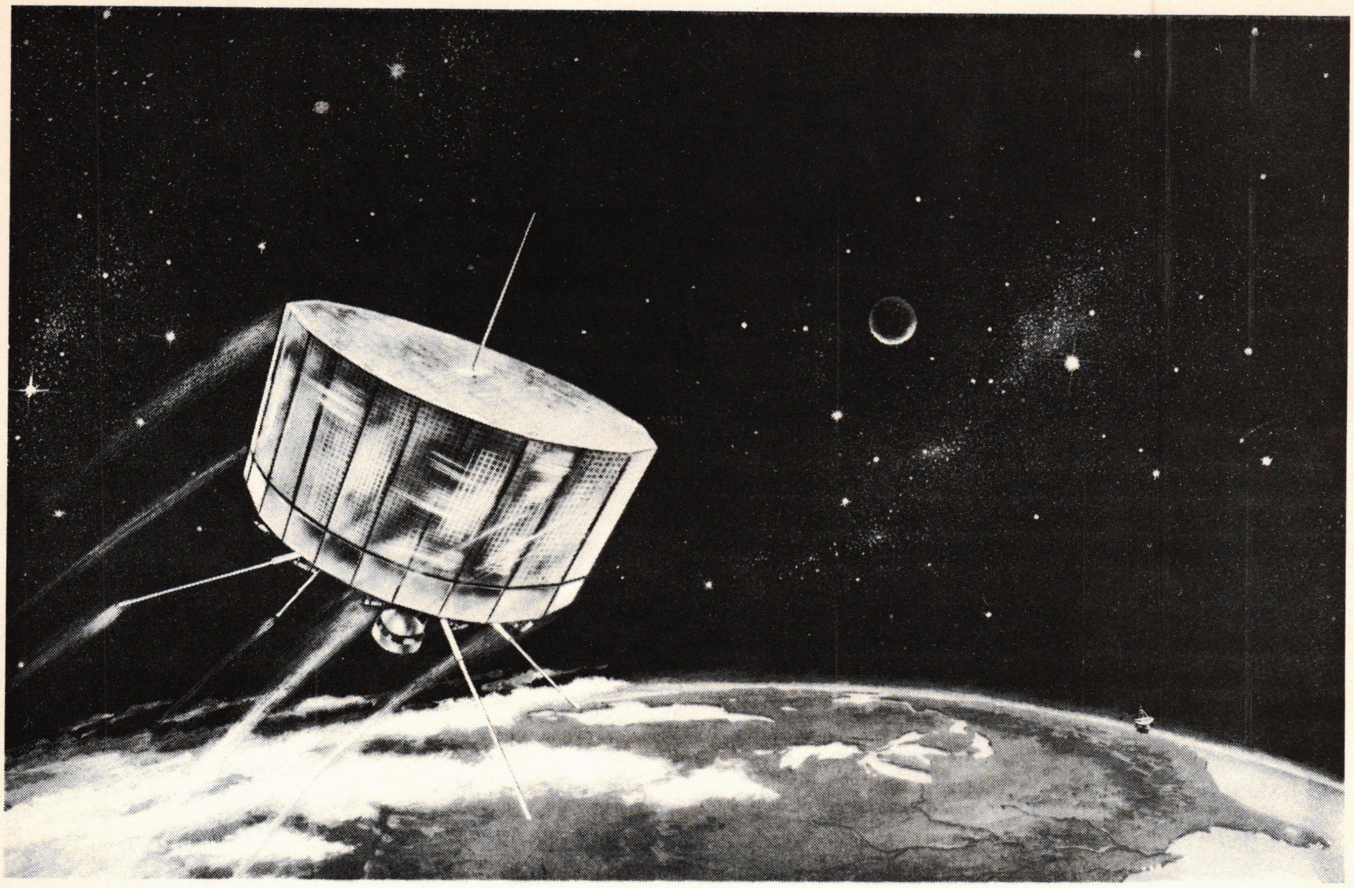
One of the largest known applications for a silicone masonry water repellent is the treatment of Indiana University's new football stadium at Bloomington, Indiana. Scheduled for completion early this fall, all seats and walkways of the curved stadium are being made from pre-cast concrete sections treated with a silicone water repellent for maximum masonry protection.

While silicone masonry water repellents have been used successfully on private homes and commercial and industrial establishments this represents the first time they have been used on a masonry structure of this type and size.

For some time, silicone-based water repellents have been recognized for their effectiveness in masonry protection. Silicones provide an invisible protective coating which minimizes water penetration without altering the original appearance of the masonry. One of the major advantages that silicones offer is the ability to repel water without sealing the masonry pores. Any trapped moisture can escape through the exterior surface at the same time that water from the outside is being repelled. As a result, this type of treatment offers masonry structures longer life, improved appearance and lower maintenance. In the construction of Indiana University's stadium, a silicone treatment was selected to prevent discoloration of the masonry and to provide long-term protection against the effects of weathering.




***The power used in the guidance system of the Sparrow III missile is supplied by the above permanent magnet.***



TIROS satellite orbiting towards ground station in Eastern United States.

# RCA-BUILT "TIROS" SATELLITE REPORTS WORLD'S WEATHER FROM OUTER SPACE

As you read these lines, the most remarkable "weather reporter" the world has ever known hurtles around our globe many times a day, hundreds of miles up in outer space.

The TIROS satellite is an orbiting television system. Its mission is to televise cloud formations within a belt several thousand miles wide around the earth and transmit a series of pictures back to special ground stations. Weather forecasters can then locate storms in the making . . . to help make tomorrow's weather forecast more accurate than ever.

*The success of experimental Project TIROS opens the door to a new era in weather forecasting—with benefits to people of all lands. This experiment may lead to advanced weather satellites which can provide weathermen with hour-by-hour reports of cloud cover prevailing over the entire world. Weather forecasts, based on these observations, may then give ample time to prepare for floods, hurricanes, tornadoes, typhoons and blizzards—time which can be used to minimize damage and save lives.*

Many extremely "sophisticated" techniques and devices were required to make *Project TIROS* a success—two lightweight satellite television cameras, an infra-red horizon-locating system, complex receiving and transmitting equipment, and a solar power supply that collects its energy from the sun itself. In addition to the design and development of the actual satellite, scientists and engineers at RCA's "Space Center" were responsible for the development and construction of a vast array of equipment for the earth-based data processing and command stations.

*Project TIROS* was sponsored by the National Aeronautics and Space Administration. The satellite payload and ground station equipment were developed and built by the Astro-Electronic Products Division of RCA, under the technical direction of the U. S. Army Signal Research and Development Laboratory.

*The same electronic skills which made possible the success of man's most advanced weather satellite are embodied in all RCA products—RCA Victor black & white and color television sets, radio and high-fidelity systems enjoyed in millions of American homes.*

RCA THE MOST TRUSTED NAME IN ELECTRONICS

RADIO CORPORATION OF AMERICA

# The Deep Sea Velocimeter

by John R. Buck, B.S.E. '63

The ocean depths are often called the fourth dimension of the sea by the men who sail the seven seas. In this so called "Space Age," many men are devoted to opening up a new frontier just as mysterious and foreign to us as outer space. These men are the scientists that are engaged in the exploration of the oceans and the ocean depths. Not only does the ocean hold many secrets of life itself, but it also contains vast amounts of mineral and chemical wealth. Man has already learned to use the oceans to his advantage through his knowledge of tides, currents, etc. If you've ever seen a nautical chart, you might wonder how the chart maker could possibly know the depth in feet of a particular spot in the middle of a bay or two miles out in the ocean. The job of obtaining pertinent data about the coastal waters of the United States falls to the Coast and Geodetic Survey, a Bureau of the U. S. Department of Commerce.

Although the Coast and Geodetic Survey is concerned with obtaining detailed information about the coastal waters of the United States as to depth, tides, currents, condition of the ocean floor, etc., other organizations such as the Woods Hole Oceanographic Institute have ships devoted exclusively to research and exploration of the ocean as a whole.

To date, only a relatively small portion of the ocean floor has been mapped. These research ships not only give information as to the contour of the ocean floor, but also facts about the type of floor (ooze, hard clay, coral head, etc.), and the many currents that flow in the ocean.

The instrument used by the Coast and Geodetic Survey to map the contour of the ocean floor is the echo sounder. The principle of the echo sounder is relatively simple, and it works just as the name implies. A sound impulse is sent from a transducer toward the ocean floor. When the impulse strikes a solid object, it bounces back and this echo is picked up by another transducer which converts it into an electrical impulse. The electrical impulse then sends an impulse into a stylus that has been moving across an electro-sensitive graph paper and immediately burns a mark on the graph paper. This operation is all done in a fraction of a second. By sending a continuous stream of sound impulses to the ocean floor, we can get an idea of the contour of the ocean floor from the graph. From the time it takes an impulse to reach the bottom and bounce back, we can compute the depth of the ocean at that particular spot by using the well known formula, $S = V \times T$. Since density and pressure can affect the speed of sound in water, we would get an incorrect reading if we assumed the speed of sound in water to be constant.

In shoal water (less than 50 ft.), it is not necessary to make a correction for the above mentioned conditions. But in water over 50 ft. deep, the readings must be corrected to get an accurate reading of the depth. The old method of correcting for this involved the use of two additional instruments, the reversible thermometer and a water sampling tube. These two were lowered together and held stationary at a certain depth to give the thermometer time to register the correct temperature. When they were pulled up, a latch released the thermometer and allowed it to flip over and the lid of the water sampling tube clamped down to enclose a sample of the water at that depth. The water was then analyzed to determine the density. This operation had to be performed at a number of various depths at one spot to get an idea of the velocity correction for the water all the way down. Obviously, this was a time consuming operation. The problem was to find a way to take into account the varying properties of the water without having

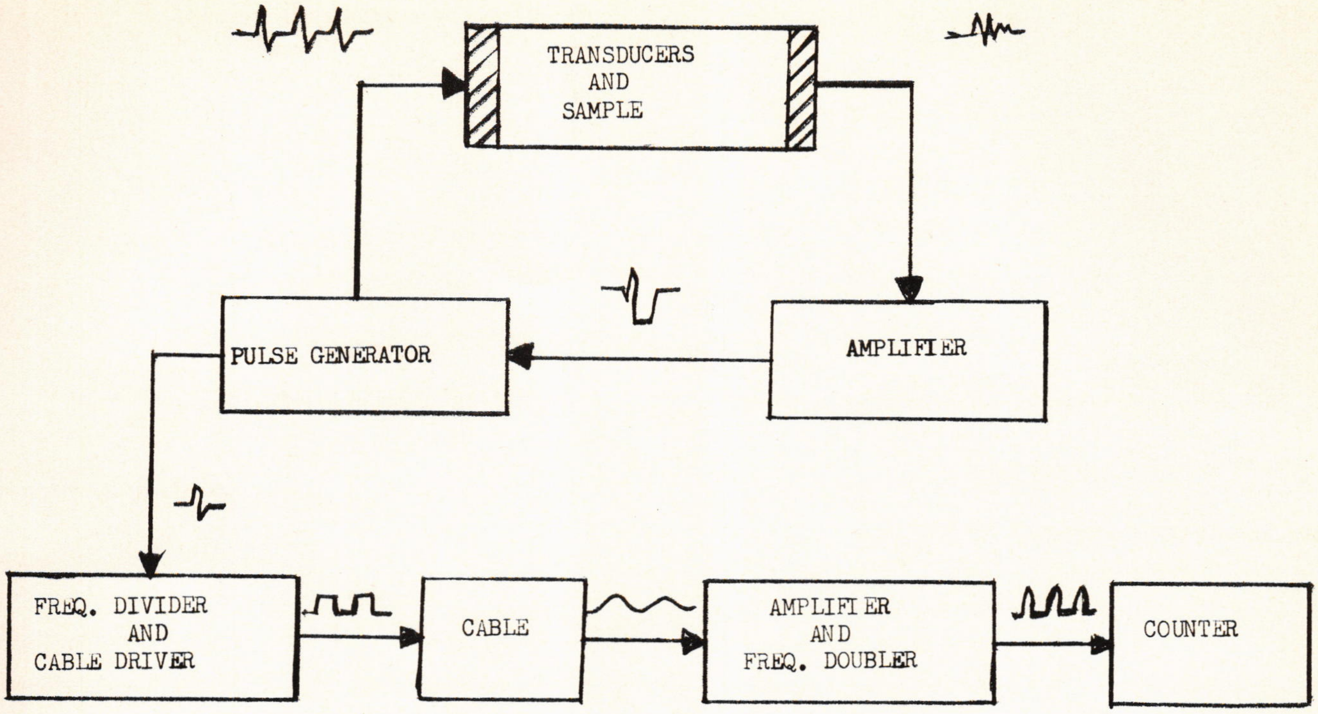



***Figure 1. Block Diagram of the Model TR-1 Velocimeter.***

to go through the lengthy process of taking the temperature at different depths and then analyzing a sample of the water from each depth to determine the density. Enter, The National Bureau of Standards.

The National Bureau of Standards had a similar request from the office of Naval Research for an instrument of this type. They developed an instrument that could be lowered over the side and would give instantly the speed of sound through water for the depth at which the reading was taken, without the cumbersome thermometer and sampling tube, and without having to analyze a sample of the water. This instrument is called the Deep Sea Velocimeter.

The velocimeter is a cylindrical instrument $13\frac{3}{4}$ inches long with a diameter of $3\frac{1}{4}$ inches. It weighs approximately 23 lbs. including its steel case. The velocimeter itself consists mainly of a pair of piezoelectric transducers of polarized barium-calcium-lead titanate with two reflectors, a pulse generator, a high gain pulse-shaping amplifier, a frequency divider to reduce cable losses, and a cable driver. These last two components of the unit are used because the cable losses of the signal are proportional to the frequency. This divided frequency is then sent up the cable to an amplifier and frequency doubler and from there to the counter.

The operation of the velocimeter is as follows: the signal generator generates an electrical impulse. This impulse goes to the sending transducer, where it is converted into a sound impulse and transmitted into the water. The sound impulse strikes the first reflector, bounces to the second reflector and then is reflected to the receiving transducer. The receiving transducer converts the sound impulse back into an electrical impulse. This received impulse is greatly distorted and rises relatively slowly due to the selective attenuation of the water. The fast rise is restored by running the impulse through an amplifier. As the signal leaves the amplifier, it passes through the pulse generator and triggers it again. Thus, this system, which is known as a sing-around-circuit, continually regenerates a sound pulse whose repetition rate, or frequency depends on the time it takes the pulse to move through the water. Since the path length is fixed at approximately 0.20 M, the frequency depends on the speed of sound through water and on constant circuit delays. Any variations in the operating frequency of the velocimeter are actually variations in the sound velocity.

The output pulse repetition rate varies from about 6.8 kc to 7.6 kc which corresponds to a path length of approximately 0.20 M. The received pulse is a burst of about 10 cycles at a frequency of 2600 kc. The first half cycle of this wave retriggers the pulse generator.

The pulse output frequency of the sing-around-circuit is approximately 7 kc. This output is converted into a square wave of 3.5 kc by means of an Eccles-Jordan type switching circuit. This lower frequency can be transmitted up the cable with reduced losses. An emitter-follower stage is used to reduce the output impedance and minimize cable loading.

Just as the sound pulse was attenuated by the water, so the output signal is attenuated by the cable. It is amplified in two stages and frequency doubled by using a full wave rectifier. From here, the signal is sent to the counter.

The speed of sound C, in M/s, is given in terms of the output frequency f, in c/s (cycles/second), by the equation

$$C = \frac{.20587 \quad (1 + C\ T)}{1/f - .4497 \times 10^{-6}}$$

Here, .20587 is the effective length of the sound path in meters, and $.4497 \times 10^{-6}$ is the effective circuit delay in seconds for this particular velocimeter. The values used


***Figure 2. Deep Sea Velocimeter. Reading from left to right: Counter, Amplifier, Velocimeter.***

*Courtesy of Coast and Geodetic Survey.*

here are representative of all velocimeters of this type. The factor $(1+c\ T)$ is a correction for the thermal expansion of the path. T is the temperature in degrees Centigrade and $^c$ may be taken as $16.4 \times 10^{-6}$ degrees Centigrade$^{-1}$ for the stainless steel of which the path determining elements are constructed.

The above equation may be approximately linearized to yield the equation

$$C = .20653\ f\ (1+c\ T)$$

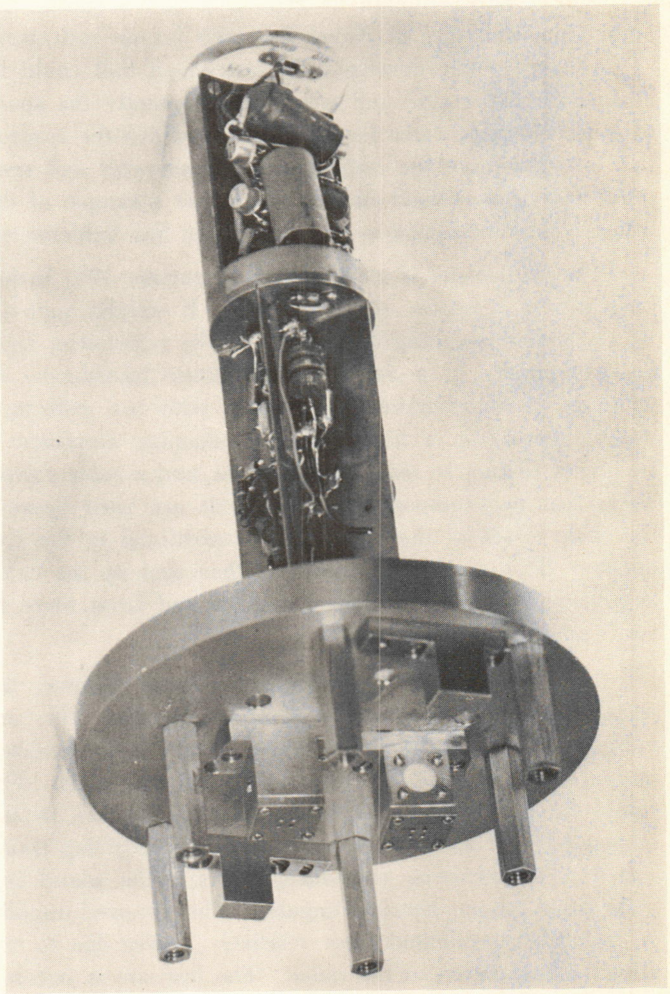
This equation is correct to within 0.3 M/s.

For greater accuracy, a correction may also be required to account for the shortening of the sound path due to pressure. When pressure is applied to the lateral sides of a closed cylinder, it tends to relieve this pressure by forcing out both ends. This ratio of the pressure in to the force out is known as Poisson's ratio. If we assume $p=29 \times 10^6$ psi and Poisson's ratio to be 0.28, the indicated value of C should be multiplied by $1-0.5 \times 10^{-9}\ p$, where p is the pressure in psi. For example, when $p=15{,}000$ psi, which corresponds to a depth of approximately 35,000 feet, the correction is about 0.1 M/s.

When the velocimeter is lowered to the bottom, the variations in the velocity of sound in water are recorded by the counter and technicians may correct the readings of the echo sounder and get a detailed picture of the floor of the ocean. This velocimeter is also useful in indicating the presence of thermoclines and sub-surface currents by the abrupt changes in the velocity of the sound.

***Figure 3. View of the base of the Velocimeter with guard removed, showing sound path. The small circular white disc is one of the transducers.*** →

*Photo by Courtesy of Coast and Geodetic Survey.*



# CAMPUS NEWS

## IRE-AIEE Prize Paper Awards

At the last meeting of the Institute of Radio Engineers and American Institute of Electrical Engineers Joint Student Branch of The George Washington University three students won prizes for outstanding technical papers in the field of electrical engineering. These three finalists, who had been previously selected from a larger group of students who entered the competition, competed for four prizes. A fifteen dollar first prize and two five dollar honorable-mention prizes are offered by the G.W.U. Branch and a ten dollar first prize by the AIEE National Headquarters. All prizes were accompanied by appropriate certificates of recognition.

Al Graps, BEE '60, won both first prizes with his paper entitled *Signal Flow Graphs.* His paper described a technique for the solution of linear network problems from a topological approach. He showed that the signal flow graph method could be used as an alternative to conventional determinant and matrix methods. Mr. Graps will present his outstanding paper at the Annual AIEE District No. 2 Prize Paper Contest on April 29 at The Drexel Institute in Philadelphia.

### Other Winners

John F. Kane, BEE '60, received honorable mention for his paper *Masers and Parametric Amplifiers.* His paper described the theory of operation of these new devices, with emphasis on their value as low-noise amplifiers in the ultra-high and super-high frequency range. Mr. Kane works full-time as an Associate Engineer at the Johns Hopkins University Applied Physics Laboratory. His work experience includes analog computer programming and missile control-system design. He is a member of the IRE-AIEE Joint Student Branch.

Arthur W. Brooks, Jr. BEE '61 also received honorable mention for his paper Induction Resolvers. He described electro mechanical trigonometeric function generator theory and suggested many applications in control systems, analog computers, and plan position indicator deflection systems. Mr. Brooks gained experience with induction resolvers during summer employment at the Bureau of Ordnance, a Department of the Navy. He is now a Cadet Major in the AFROTC, and member of the Arnold Air Society, Sigma Tau, and the IRE-AIEE Joint Student Branch.

### Judged by Profs

Pre-selection of the three prize papers was made by Professors Nelson Grisamore and Louis de Pian of the G.W.U. Electrical Engineering Department. Final judging was done after their presentation at the April 6 meeting by Mr. Ben. S. Melton, civilian employee of Headquarters USAF, and Secretary of the Washington Section of IRE; by Assistant Professor Llewellyn A. Rubin of the G.W.U. Electrical Engineering Department, and by Mr. George Abraham, civilian employee at the US Naval Research Laboratory, and lecturer in Electrical Engineering at G.W.U. The papers were judged in accordance with standards formulated by the AIEE which emphasized originality, analytical treatment, interest, mode of expression, speaking technique, style, introduction and conclusion, skillful use of visual aid, and proficiency in answering questions from the floor. The presentation of each paper was limited to twenty minutes.

The success of this contest suggests that it should become an annual event.

Bob Sanborn

# Letters to The Editor

Dear Editor:

I am writing in reference to the editorial in this month's *Mechelecív* which I had a chance to preview. It is hard to believe that the editors of your magazine could possibly condone or defend student apathy. Surely there would be no *Mecheleciv* if there had not been some energetic students who felt it their "duty" to establish such a publication.

Student support *is* a duty of every student in this university. This is our school and for many, our whole lives. To deny it support is to deny support to the very end you are trying to achieve —education. Better standards and levels of teaching and education cannot be obtained without an organized, fully represented, student body.

Organizations such as the Student Council and the Engineers' Council strive continually to insure the student that he may have "Academic Freedom." Education is far more than hard, cold facts from the classroom. It is the development of personalities, the sharing of ideas, and most important, the stepping stone to man's peaceful coexistence.

The student who choses to be apathetic is betraying his academic freedom, for he will deny himself that essential part of his education which will teach him to work and live with his fellow man.

Daniel B. Havens

Dear Ed.:

The Norman B. Ames Memorial Fund is progressing rapidly as contributions are being received. Each year the income from the fund will be used to provide an award which will be presented to a graduating engineering student. The student will be judged on the basis of scholastic standing and extra-curricular activities. The first award will be presented this June.

A temporary committee to establish

**LETTERS** *(Continued)*

and administer this fund has been set up and consists of:

John B. Pyle, Chairman-Treasurer
John W. Roberts, Secretary
Dr. H. S. Hoffman, Consultant-Advisor
David Lokerson
Donald Lokerson
Herbert H. Rosen
William J. Ellenberger

It is expected that the fund will be turned over to the University for future administration.

It was felt that the readers of your magazine would want to contribute to this fund. This they may do by making their checks payable to "The Norman B. Ames Memorial Fund," and sending them to:

John B. Pyle
4 Wyoming Court
Glen Echo Heights
Washington 16, D. C.

Contributions of any amount will be appreciated.

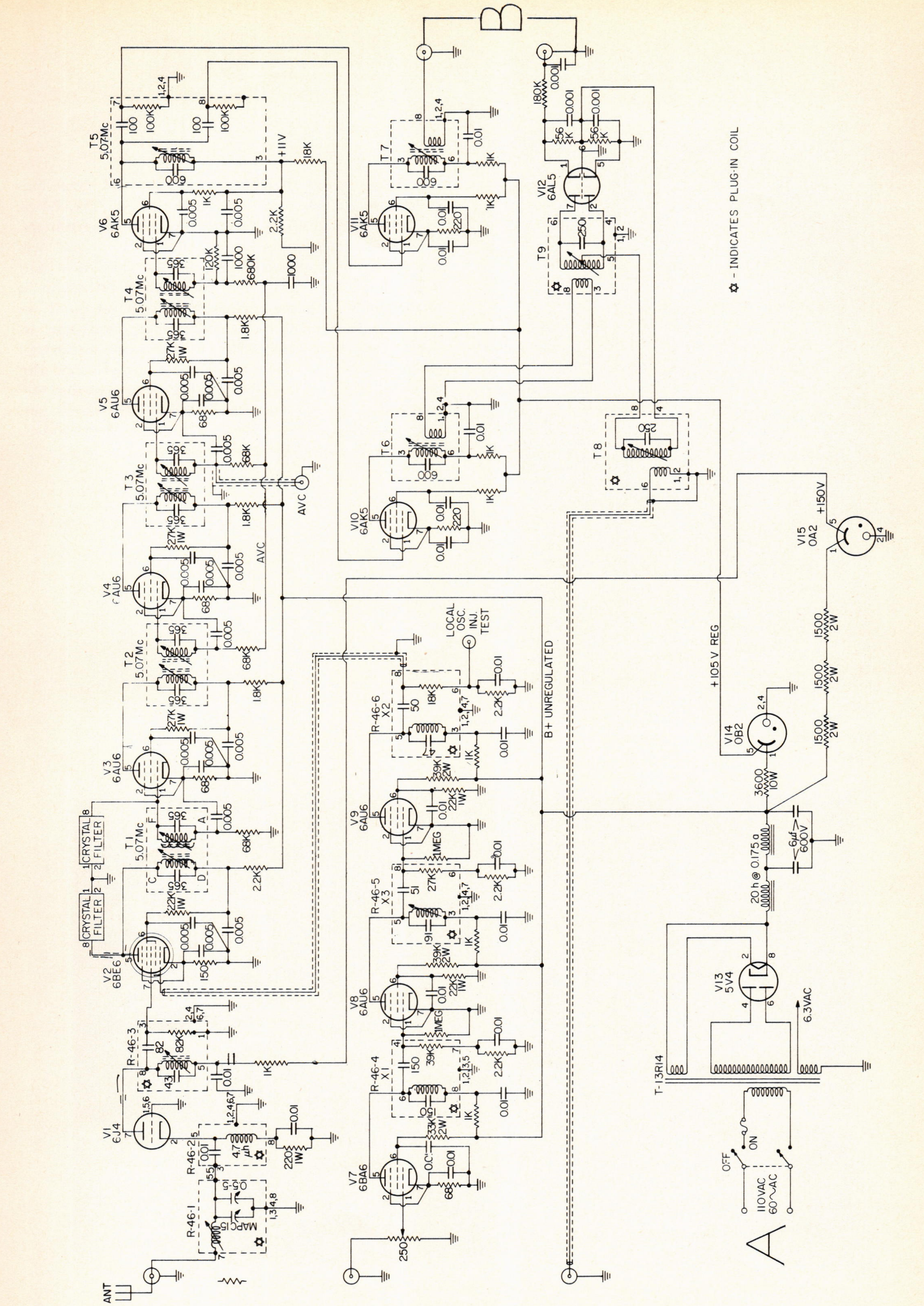
Sincerely,
John W. Roberts
Secretary

## *Engineering Advances*

**Third of a Series**

Throughout the last few months, the D-H Laboratories have put on an extensive and intensive search for a perfect electronic switch. This switch serves as an intermediate between the mechanical switch and the light which is to be switched. Note the mechanical switch at A. Note the light bulb at B. When the switch at A is thrown, the light bulb at B lights, provided the proper voltages are maintained at the plates and other electrodes of the circuit components. This switch has the immediate applicability of being very expensive and a good item with which to pad bills. Other uses for this useless device can be thought of at your leisure.

This device was developed under contract no. GS-81186904-002B; its purpose is for use in turning on and off the bilge light (MIL-STD-E-9696) of the Galvanic Pornoscope. (See March issue).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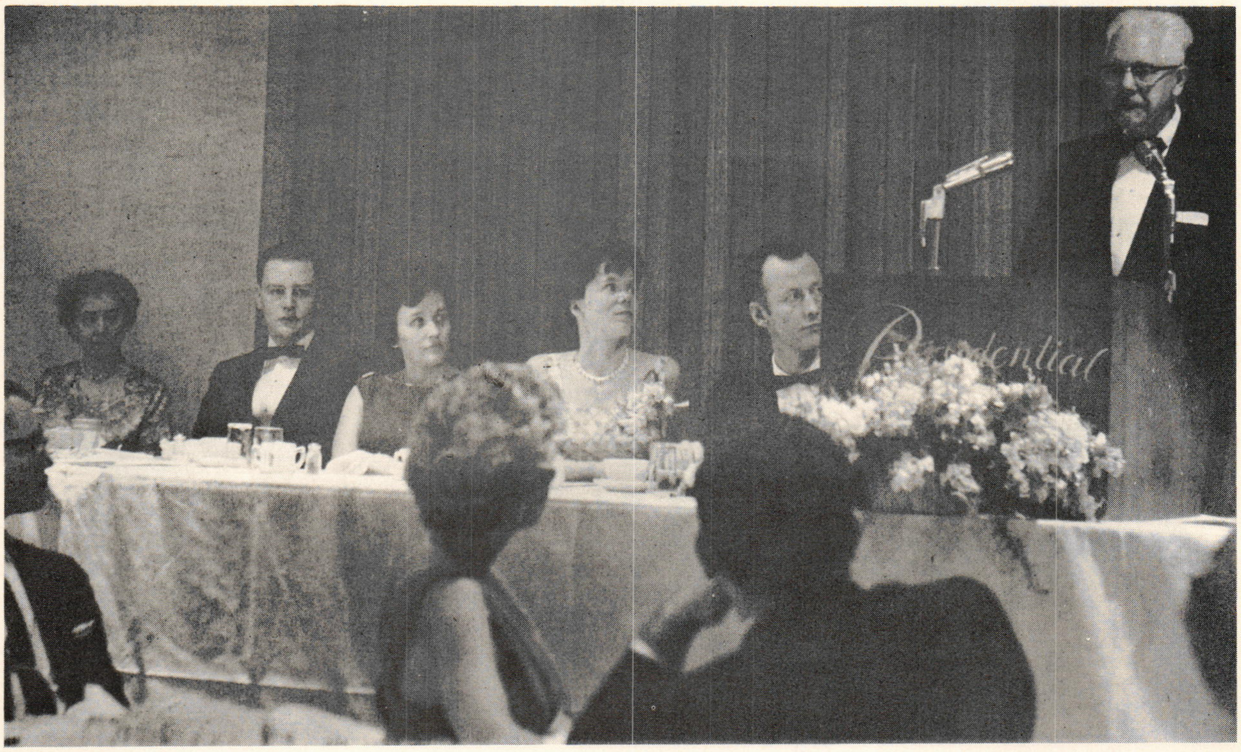
- INDICATES PLUG-IN COIL

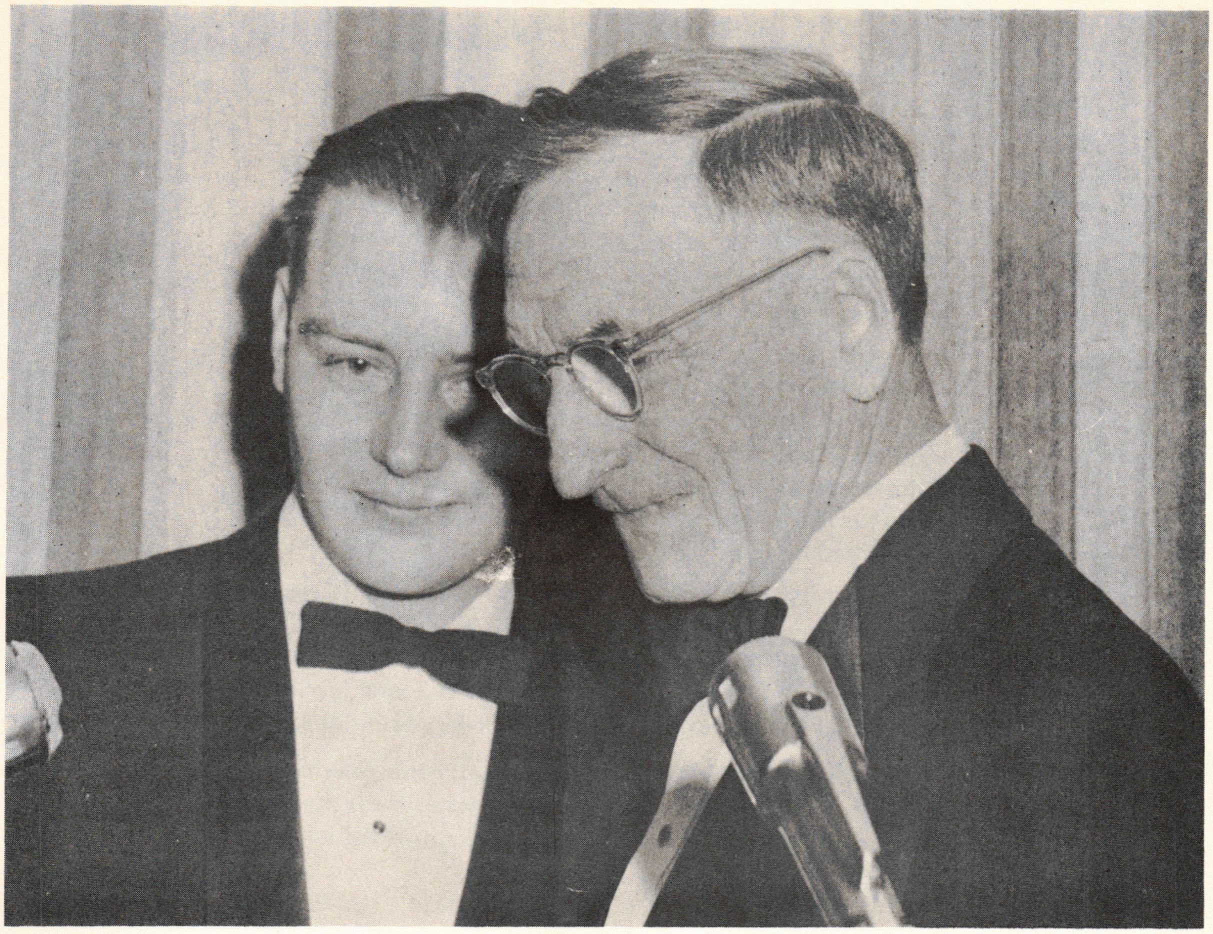
# ENGINEERS' BANQUET and BALL

*Helene Harper being crowned 1960 Engineering Queen.*

Like, it was that time again, and all those Engineers in the know had made the scene, like, down to the Presidential Arms to view the proceedings. First, man, there was food, followed by some presentations of keys and the like, to those who had done it during the year Then some fellow in a beard made with the speech and math yet, as if we didn't know what it was or something, and then, at last, finally came the time for the more important endeavors. Like man there were set-ups for the 100 proof. And Swinging Al Graps blowing the cool notes on not one but two different horns yet. And the chicks were like wow, man. And the noises the swingin'est. Like it was the most.



*The big wheels at the head table. The speaker was Dr. Page of the NRL who spoke on Communication and the Engineer.*



*One of the recipients of an Engineers' Council key. All new members of the Council and of the staff of MECHELECIV received keys at the Banquet.*

# Faculty Page

Dr. Ernest Frank, Executive Officer of the Department of Electrical Engineering, is leaving the University. It is with regret that we comment on his departure, for he certainly ranks among the best of men in his profession.

Dr. Frank came to the George Washington University four years ago, after having taught at the University of Pennsylvania for nine years. He assumed the position of Executive Officer of the EE Department, and with his leadership the EE Department underwent vast improvements, particularly in curriculum.

Although Dr. Frank is known as a "hard man to get a grade from", his performance as a teacher and advisor demands respect and admiration. His inspired dedication will remain with us, and his lecture notes are among our treasured possessions.

Wherever Dr. Frank's future activities may take him, we wish Dr. Frank much success, and express our gratitude for having had the opportunity to learn from him.


# IT'S LITERALLY ALL AROUND YOU!

The word *space* commonly represents the outer, airless regions of the universe. But there is quite another kind of "space" close at hand, a kind that will always challenge the genius of man.

This space can easily be measured. It is the space-dimension of cities and the distance between them . . . the kind of space found between mainland and off-shore oil rig, between a tiny, otherwise inaccessible clearing and its supply base, between the site of a mountain crash and a waiting ambulance—above all, Sikorsky is concerned with the precious "spaceway" that currently exists between all earthbound places.

Our engineering efforts are directed toward a variety of VTOL and STOL aircraft configurations. Among earlier Sikorsky designs are some of the most versatile airborne vehicles now in existence; on our boards today are the vehicles that can prove to be tomorrow's most versatile means of transportation.

Here, then, is a space age challenge to be met with the finest and most practical engineering talent. Here, perhaps, is the kind of challenge *you* can meet.

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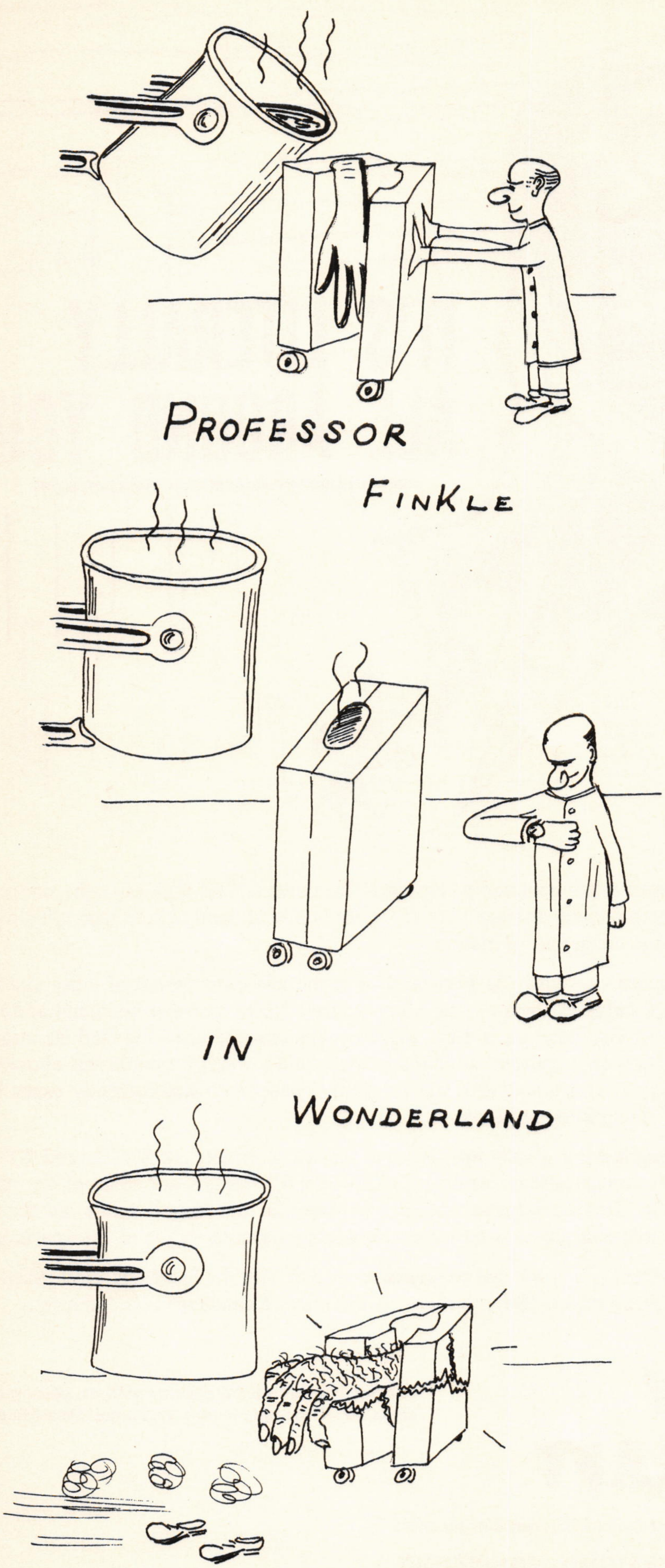
*One of the Divisions of United Aircraft Corporation*

**STRATFORD, CONNECTICUT**

**For information about careers with us, please address Mr. Richard L. Auten, Personnel Department.**




A couple of sailors laying over for a day or two in Sweden decided to go to church. Knowing no Swedish, they figured to play safe by picking out a dignified looking gentleman sitting in front of them and doing whatever he did.

During the service the pastor made a special announcement of some kind and the man in front of them started to rise, at which the two sailors quickly got to their feet, to be met by roars of laughter from the whole congregation.

When the service was over and they were greeted by the pastor at the door, they discovered he spoke English and naturally asked what the cause of merriment had been.

"Oh," said the pastor. "I was announcing a baptism and asked the father of the child to stand."

* * *

"This College turns out some great men."

"When did you graduate?"

"I didn't. I was turned out."

* * *

A salesman making a week's stay in town bought some limburger cheese to eat in his room. When he got ready to leave, he still had part of it left. Not wanting to pack it or leave it lying open in the room, he went to the window sill, carefully removed a plant from its pot, buried the cheese and replaced the plant.

A few days later he got a telegram from the hotel: "O. K., we give up. Where in hell did you hide it?"

* * *

The legend is told that in the days of yore, when knighthood was in flower, a knight, called away to the wars, locked his beautiful young wife in armor and gave the key to his best friend with the admonition: "If I don't return in six months, use this key. To you my dear friend, I entrust it."

Ten miles away from home, he saw a cloud of dust approaching and waited.

His friend, on horseback, galloped up saying: "You gave me the wrong key."

* * *

Two bopsters in a museum spotted a bust of Julius Caesar. One said to the other, "This guy's been gone for 2000 years."

"Man," the other replied. "Those Romans really knew how to live."

* * *

She: I don't believe you know what good clean fun is.

Me: All right, what good is it?

* * *

Young wife dejectedly—My husband never used to snore before we were married.

* * *

Lady, if you'll give us a nickel, my brother will imitate a hen.

What will he do, cackle?

No, he'll eat a worm.

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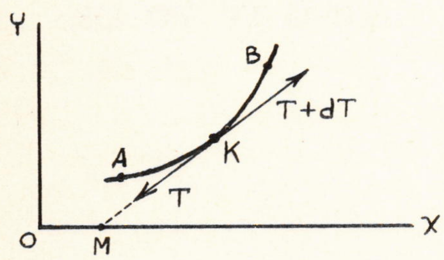
## Answer to Monthly Quiz

### A PROBLEM IN DYNAMICS*

*by JAMES CLERK MAXWELL*

An inextensible heavy chain
Lies on a smooth horizontal plane,
An impulsive force is applied at A,
Required the initial motion of K.
Let ds be the *infinitesimal* link,
Of which for the present we've only to think;
Let T be the tension, and T+dT
The same for the end that is nearest to B,
Let $\alpha$ be put, by a common convention,
For the angle at M 'twixt OX and the tension;
Let $V_t$ and $V_n$ be ds's velocities
Of which $V_t$ along and $V_n$ across it is;
Then $\frac{V_n}{V_t}$ the tangent will equal,
Of the angle of starting worked in the sequel.
In working the problem the first thing of course is
To equate the impressed and effectual forces.
K is tugged by two tensions, whose difference dT
Must equal the element's mass into $V_t$ (1)**
$V_n$ must be due to the force perpendicular
To ds's direction, which shows the particular
Advantage of using $\alpha$ to serve your
Pleasure to estimate ds's curvature,
For $V_n$ into mass of a unit of chain
Must equal the curvature into the strain. (2)
Thus managing cause and effect to discriminate
The student must fruitlessly try to eliminate
And painfully learn, that in order to do it, he
Must find the equation of continuity.
The reason is this, that the tough little element,
Which the force of impulsion to beat to a jelly meant,
Was endowed with a property incomprehensible,
And was "given", in the language of *Shop,* "inextensible".
It therefore with such pertinacity odd defied
The force which the length of the chain would have modified,
That its stubborn example may possibly yet recall
These overgrown rhymes to their prosady metrical.
The condition is got by resolving again,
According to axis assumed in the plane.
If then you reduce to the tangent and normal
You will find the equation more neat tho' less formal. (3)
The condition thus found after these preparations, (4)
When duly combined with the former equations,
Will give another, in which differentials,
(When the chain forms a circle), become in essentials (5)
No harder than those that we easily solve
In the time a T totum would take to resolve. (6)
Now joyfully leaving ds to itself, a-
Tt end to the values of T and of $\alpha$
The chain undergoes a distorting convulsion
Produced first at A by the force of impulsion.
In magnitude R, in direction tangential,
Equating this R to the form exponential (7)
Obtained for the tension when   is zero,
It will measure the tug, such a tug as the "hero
Plume-waving" experienced, tied to the chariot
But when dragged by the heels his grim head could not carry
aught.
So give $\alpha$ its due at the end of the chain, (8)
And the tension ought there to be zero again.
From these two conditions we get three equations
Which serve to determine the proper relations
Between the first impulse and each coefficient
In the form of the tension, and then this is sufficient
To work out the problem, and then, if you choose,
You may turn it and twist it the Dons to amuse.




1) $dT = m V_t \, ds$

2) $m V_n = T \frac{d\alpha}{ds}$

3) $\frac{dV_t}{ds} = V_n \frac{d\alpha}{ds}$

4) $\frac{d^2T}{ds^2} - T\left(\frac{d\alpha}{ds}\right)^2 = 0$

5) $\frac{d^2T}{d\alpha^2} - T = 0$

6) $T = c_1 \epsilon^{\alpha} + c_2 \epsilon^{-\alpha}$

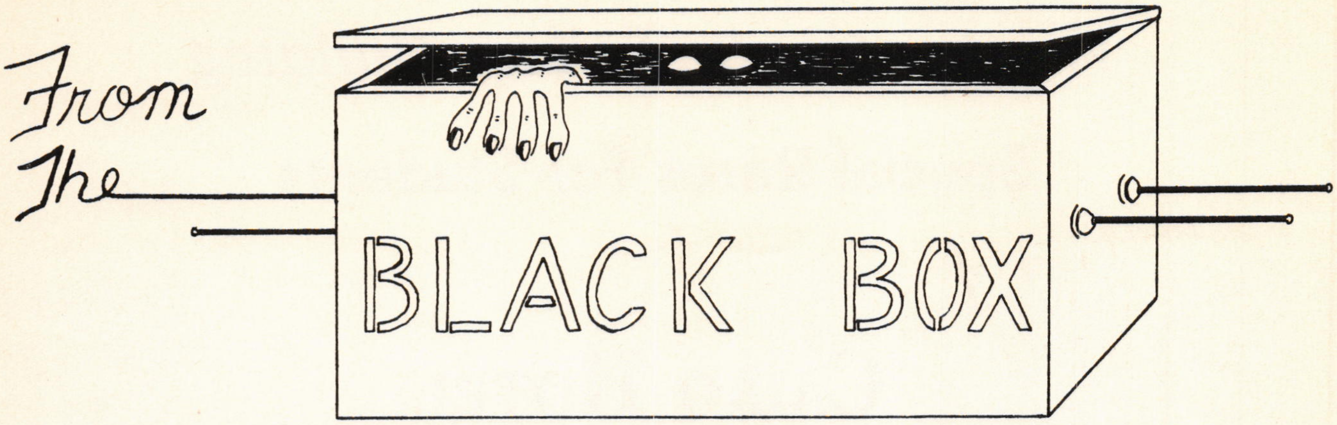
7) $R = c_1 + c_2$

8) $0 = c_1 \epsilon^{\alpha_1} + c_2 \epsilon^{-\alpha_1}$

$$\frac{V_n}{V_t} = \tan\beta = -\frac{\epsilon^{(\alpha_1-\alpha)} - \epsilon^{-(\alpha_1-\alpha)}}{\epsilon^{(\alpha_1-\alpha)} + \epsilon^{-(\alpha_1-\alpha)}}$$

* *Ed. Note.* Any similarity between this poem and Prof. Rubin's exams is purely coincidental.

* The numbers refer to the equations at the end of the text.




Coed: I'm sorry that I slapped you, really I am. I thought that you were reaching for my sorority pin.

* * *

He: "Have you a room and bath for my wife and me?"

Hotel clerk: "All we have left is a room with a double bed."

He: "Will that be all right with you, Dearest?"

She: "Yes, Mister."

* * *

Some girls go to such lengths to get a mink coat that when they finally get one, they have trouble buttoning it.

* * *

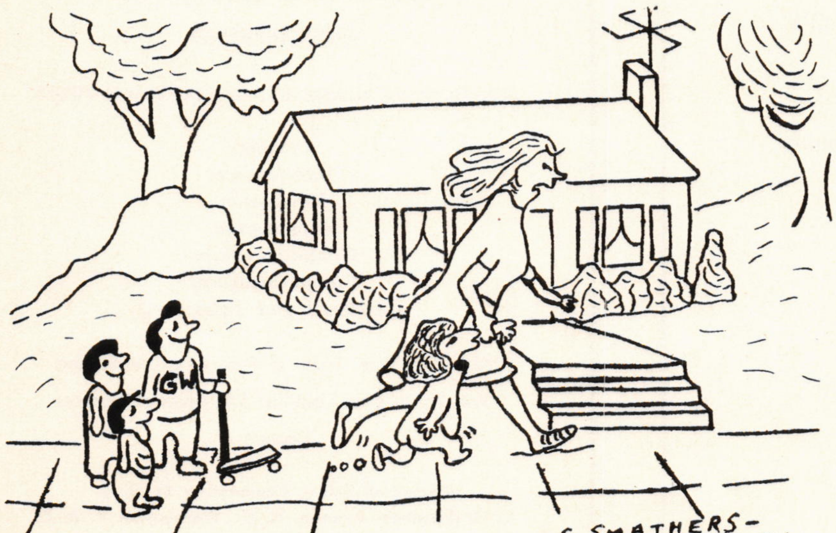
This is a really bad year for college graduates. Everyone who tries is expected to get a job.

* * *

While visiting America, a lovely French maiden discovered both her visa and her money had vanished. She was in great despair until an enterprising young sailor came to her rescue.

"My ship is sailing tonite," he said. "I'll smuggle you aboard, hide you in the hold and provide you with food and blankets. All it will cost you is a little affection."

She consented and he carried out his promise, visiting her several times daily. This went on for several weeks until one day the captain of the ship discovered the sailor paying her a visit. After the sailor had gone, he confronted the girl and upon hearing her sad story mused, "I admire the young seaman's ingenuity. However, I feel it's only fair that I inform you this is the Staten Island Ferry."




*"Well, if a girl's got a good figure she ought to show it off."*

"Darling, I have a confession to make," said the shy young bride at their first breakfast. "It isn't a big thing, but I feel I should have told you before that I suffer from asthma."

"Thank heavens," said the groom. "Last night I thought you were hissing me."

* * *

"Anything else, sir?" asked the attentive bellhop trying his best to make the lady and gentleman comfortable in their penthouse suite at the plush hotel.

"No, thank you," replied the gentleman.

"Anything for your wife, sir," the bellboy asked.

"Why, yes young man," said the gentleman. "Would you bring me a post card."

* * *

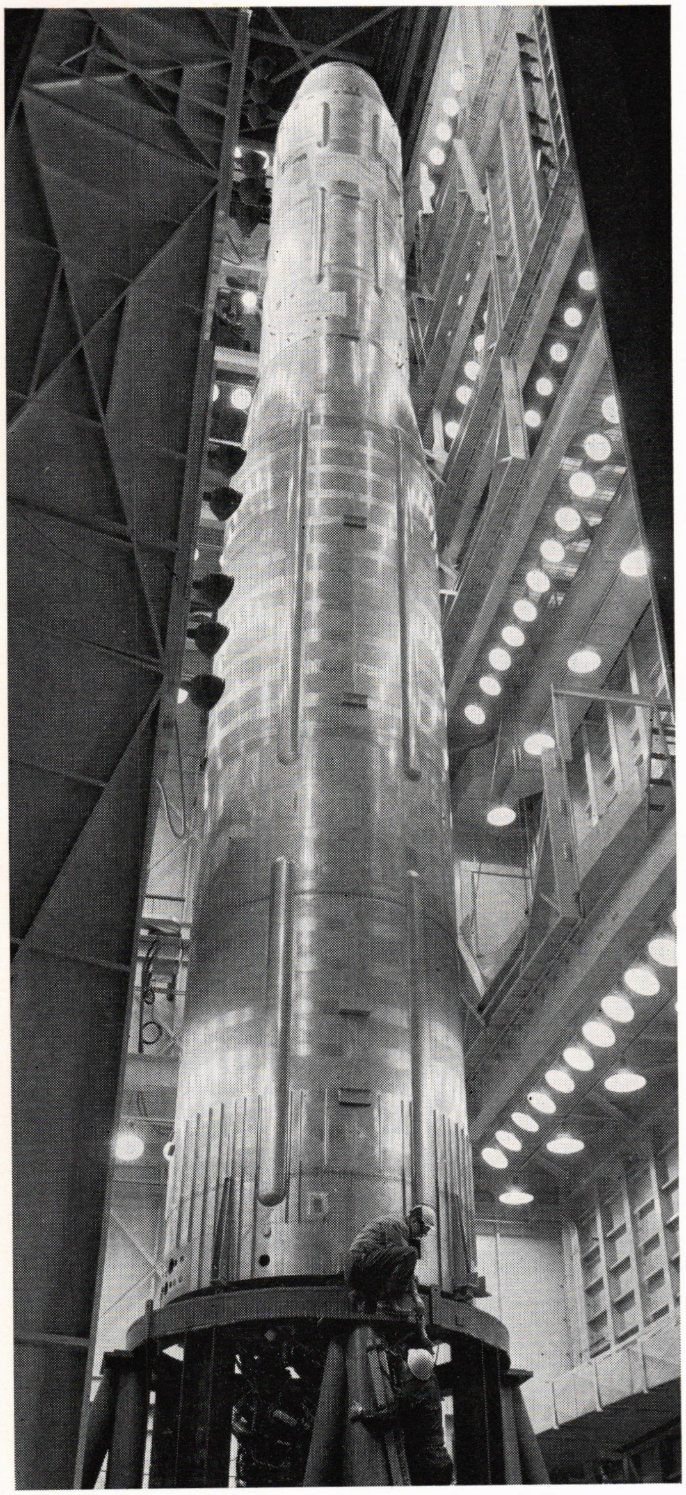
Next to lightning, scientists have observed that the fastest moving thing is a nudist who has just spilled hot coffee in his lap.

* * *

The older generation is quite upset about the state of the world these days, but they would be even more concerned if they realized that the modern Cinderella turns into a motel every midnight.

# If your sights are set  on outer space–





U.S. Air Force I.C.B.M. "Titan" shown in the vertical test laboratory at the Martin Company, Denver, Colorado.

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One of a series

*Interview with*
*General Electric's Byron A. Case*
*Manager—Employee Compensation Service*

# Your Salary at General Electric

Several surveys indicate that salary is not the primary contributor to job satisfaction. Nevertheless, salary considerations will certainly play a big part in your evaluation of career opportunities. Perhaps an insight into the salary policies of a large employer of engineers like General Electric will help you focus your personal salary objectives.

Salary—a most individual and personal aspect of your job—is difficult to discuss in general terms. While recognizing this, Mr. Case has tried answering as directly as possible some of your questions concerning salary:

**Q Mr. Case, what starting salary does your company pay graduate engineers?**

**A** Well, you know as well as I that graduates' starting salaries are greatly influenced by the current demand for engineering talent. This demand establishes a range of "going rates" for engineering graduates which is no doubt widely known on your campus. Because General Electric seeks outstanding men, G-E starting salaries for these candidates lie in the upper part of the range of "going rates." And within General Electric's range of starting salaries, each candidate's ability and potential are carefully evaluated to determine his individual starting salary.

**Q How do you go about evaluating my ability and potential value to your company?**

**A** We evaluate each individual in the light of information available to us: type of degree; demonstrated scholarship; extra-curricular contributions; work experience; and personal qualities as appraised by interviewers and faculty members. These considerations determine where within G.E.'s current salary range the engineer's starting salary will be established.

**Q When could I expect my first salary increase from General Electric and how much would it be?**

**A** Whether a man is recruited for a specific job or for one of the principal training programs for engineers—the Engineering and Science Program, the Manufacturing Training Program, or the Technical Marketing Program—his individual performance and salary are reviewed at least once a year.

For engineers one year out of college, our recent experience indicates a first-year salary increase between 6 and 15 percent. This percentage spread reflects the individual's job performance and his demonstrated capacity to do more difficult work. So you see, salary adjustments reflect individual performance even at the earliest stages of professional development. And this emphasis on performance increases as experience and general competence increase.

**Q How much can I expect to be making after five years with General Electric?**

**A** As I just mentioned, ability has a sharply increasing influence on your salary, so you have a great deal of personal control over the answer to your question.

It may be helpful to look at the current salaries of all General Electric technical-college graduates who received their bachelor's degrees in 1954 (and now have five years' experience). Their current median salary, reflecting both merit and economic changes, is about 70 percent above the 1954 median starting rate. Current salaries for outstanding engineers from this class are more than double the 1954 median starting rates and, in some cases, are three or four times as great.

**Q What kinds of benefit programs does your company offer, Mr. Case?**

**A** Since I must be brief, I shall merely outline the many General Electric employee benefit programs. These include a liberal pension plan, insurance plans, an emergency aid plan, employee discounts, and educational assistance programs.

The General Electric Insurance Plan has been widely hailed as a "pace setter" in American industry. In addition to helping employees and their families meet ordinary medical expenses, the Plan also affords protection against the expenses of "catastrophic" accidents and illnesses which can wipe out personal savings and put a family deeply in debt. Additional coverages include life insurance, accidental death insurance, and maternity benefits.

Our newest plan is the Savings and Security Program which permits employees to invest up to six percent of their earnings in U.S. Savings Bonds or in combinations of Bonds and General Electric stock. These savings are supplemented by a Company Proportionate Payment equal to *50 percent* of the employee's investment, subject to a prescribed holding period.

***If you would like a reprint of an informative article entitled, "How to Evaluate Job Offers" by Dr. L. E. Saline, write to Section 959-14, General Electric Co., Schenectady 5, New York.***

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